The Frequency and Functions of Involuntary and Voluntary Autobiographical Memories Across the Day

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Abstract

Involuntary autobiographical memories are memories of personally experienced events that come to mind spontaneously, whereas voluntary (i.e., deliberately recalled) memories are based on strategic retrieval processes, reflecting a goal-directed search. Previous work using an on-line recording methodology (i.e., a mechanical counter) has shown that involuntary compared with voluntary memories are three times as frequent in daily life, but there is evidence to suggest that frequency estimates of involuntary memories are sensitive to the methods used to make the recordings. Here, we use different types of on-line recording devices across three studies. In Study 1, using a mechanical counter, we replicated previous work showing that involuntary memories are almost three times as frequent as their voluntary counterparts. In Studies 2 and 3, we used smartphones to assess on-line frequency and found that the shift in recording device led to a decrease in the frequency of involuntary but not of voluntary memories. Furthermore, the smartphone assessment showed that involuntary memories were more frequent in the middle of the day, whereas voluntary retrieval was evenly distributed across the day. Voluntary relative to involuntary memories were estimated to serve more problem solving and directive functions in Studies 1 and 2 and as being more functionally relevant to the ongoing situation in Study 3. In conclusion, regardless of recording device, involuntary memories are at least as frequent as their voluntary counterparts, but are perceived to be less functionally relevant to the immediate retrieval context.

The Frequency and Function of Involuntary and Voluntary Autobiographical Memories Across the Day

Involuntary autobiographical memories are memories of personally experienced events that come to mind spontaneously – that is, with no immediately preceding attempts at retrieval (Berntsen, 1996). In contrast, voluntary (i.e., deliberately recalled) memories are based on strategic retrieval processes, reflecting a goal-directed and controllable search. For many years, cognitive psychologists regarded voluntary remembering as the standard way of remembering autobiographical events, whereas involuntary remembering was seen as a rare type of retrieval (e.g., Davachi & Dobbins, 2008; Miller, 1962/1974; Tulving, 1983) or as a pathological response to traumatic events (e.g., Brewin, Dalgleish & Joseph, 1996; Ehlers & Clark, 2000). However, research from the last twenty years repeatedly has demonstrated that autobiographical memories can come to mind both voluntarily and involuntarily, and that involuntary memories are frequent in the daily life of healthy individuals and can be associated with positive as well as negative emotion (e.g., Berntsen, 1996, 2009; 2010; Finnbogadottir & Berntsen, 2013; Rasmussen & Berntsen, 2011; Walker, Skowronski & Thompson, 2003; Watson, Berntsen, Kuyken & Watkins, 2012).

In order to examine the frequency of involuntary and voluntary memories, Rasmussen and Berntsen (2011) randomly assigned participants to record either involuntary or voluntary memories during a normal day. The participants were instructed to carry a mechanical counter and to register each time they had an involuntary or (depending on group assignment) a voluntary memory. The recordings were to be done immediately after the retrieval of each memory. Rasmussen and Berntsen found that involuntary memories were recorded three times as frequently as voluntary memories. At the end of the day, after finishing the frequency task, the participants answered a questionnaire in which they retrospectively assessed functions and characteristics of the recorded

memories. The retrospective ratings showed that there were no differences between the two types of retrieval with respect to (a) whether the memories served self-functions or were elicited by internal or external cues, (b) their temporal distribution across the day, and (c) the emotional valence of the memories. However, the participants reported that the retrieval of voluntary relative to involuntary memories took place during situations characterized by higher levels of concentration and had higher ratings on problem solving and social sharing functions (e.g., Pillemer, 1992; 2003; Rasmussen & Berntsen, 2009a; b), whereas the involuntary memories to a greater extent were associated with periods of boredom, daydreaming, and no reasons for remembering. Rasmussen and Berntsen (2011) suggested that a key to understanding the adaptive value of involuntary memories may be their relative abundance combined with their effortless retrieval driven by feature overlaps between the past and the retrieval context. Taken together, these factors can be seen to strike a balance between optimizing the probability of situational relevance and minimizing the cognitive costs associated with the retrieval of the involuntary memories (for more elaborated discussions of this issue, see Berntsen, 2009; Berntsen, 2012; Rasmussen & Berntsen, 2009b).

The purpose of the present series of studies is to examine the frequency and function of involuntary memories. In Study 1 we therefore attempt to replicate the findings from Rasmussen and Berntsen (2011) using the mechanical counter and a retrospective questionnaire. In Study 2, we extend these findings with on-line smartphone recordings of the frequency and temporal distribution of involuntary and voluntary memories across the day, followed by the retrospective questionnaire used in Study 1 and by Rasmussen and Berntsen (2011). In Study 3, we eliminate retrospective measures and use the smartphones to assess frequency, temporal distribution, concentration at time of retrieval, emotional valence and perceived functional relevance on-line immediately after retrieval. We first review previous research on the frequency of involuntary memories as well as

related methodological challenges. We then describe possible functional differences between involuntary and voluntary memories.

Studies on the Frequency of Involuntary Autobiographical Memories

For many years, it was a widely held assumption in cognitive and clinical psychology that voluntary retrieval was the normative way of remembering the personal past, whereas involuntary remembering was regarded as the exception (e.g., Davachi & Dobbins, 2008; Miller, 1962/1974; Tulving, 1983) or as a sign of dysfunction and emotional stress in response to traumatic experiences (e.g., Brewin et al., 1996; Ehlers & Clark, 2000). Although a number of diary and survey studies have now demonstrated that involuntary memories are frequent in daily life and mainly differ from their voluntary counterparts with respect to retrieval mode (e.g., Berntsen, 1996, 2009; 2010; Rubin & Berntsen, 2009), little is known about the actual frequency of involuntary as compared to voluntary memories. Rubin and Berntsen (2009) asked large stratified samples of Danes to assess how often they had involuntarily as well as voluntarily thought about a self-chosen important event from the last week and an important childhood event selected by the experimenter. The participants reported the involuntary remembering of the events to have taken place about as frequently as the voluntary counterpart. Moreover, when informally asked during a debriefing interview after the completion of a diary study, participants typically estimated having five to six involuntary memories at average per day (e.g., Berntsen, 2009). However, this estimate varies greatly between individuals and also within individuals depending on variations in daily activities, but nonetheless, suggests that involuntary memories are common in the daily life of healthy individuals. Importantly, because they are based on retrospective assessment, the estimates do not speak directly of the moment-to-moment frequencies of daily remembering. Since involuntary memories are transient by nature, and often concerns trivial everyday events, retrospective assessments may easily

underestimate the actual frequency of involuntary memories (Rasmussen & Berntsen, 2011; Takarangi, Strange & Lindsay, 2014).

Few studies have assessed the on-line moment-to-moment frequency of involuntary memories. Furthermore, such estimates are very sensitive to the methods used to make the recordings. For instance, Schlagman and Kvavilashvili (2008) found that participants reported 10 to 15 involuntary memories in a diary over a seven-day period, corresponding to 1 to 2 memories on a daily basis. Importantly, the participants were not explicitly instructed to make records of all involuntary memories that happened during the diary period. When asking participants to report all involuntary or voluntary memories that happened during a day, Rasmussen and Berntsen (2011) found an average of 22 involuntary memories per day, whereas the corresponding average for voluntary memories was seven. This estimate of daily frequency of involuntary memories was replicated by Finnbogadottir and Berntsen (2013), who also found an average of about 20 involuntary memories per day. Finally, in a recent study, Kamiya (2014) instructed participants to walk around the university campus in 30-90 minute sessions and report all involuntary memories that came to mind during the walk. On average the participants reported 12 involuntary memories per session. Hence, the existing research suggests that frequency estimates of involuntary memories may be easily affected by factors related to different methodologies, such as for instance, the workload or recording effort associated with the task as well as the distinction between on-line versus retrospective assessment.

Involuntary autobiographical memories generally have been examined with a combination of on-line and retrospective methods (see Berntsen, 2009, for an overview). However, some variables, such as frequency, are sensitive to differences between these two types of assessment methods, whereas others may be less affected. Although on-line as compared to retrospective assessment may be thought of as being a more direct measure of conscious experiences, the former requires a great

deal of effort on behalf of the participants, which again may increase the probability of non-compliance and participant fatigue (Scollon, Chu & Diener, 2009). Hence, when examining reactions to, and characteristics of, involuntary autobiographical memories in daily life, researchers typically attempt to achieve a balance between on-line and retrospective measures in order to minimize the task demands and to address the central research questions with the relevant type of assessment. Variables related to the retrieval context and the “here and now” reaction to the memory generally are regarded as being sensitive to whether the assessment is conducted on-line or retrospectively, whereas more enduring memory characteristics, such as their perceived importance or prior rehearsal, are assumed to be less sensitive to retrospection (e.g., Berntsen, 1996; 2009).

One factor, which may influence the differences in frequency estimates, is that involuntary memories may be more frequent than their voluntary counterparts during certain time periods over the course of the day. The retrospective reports in Rasmussen and Berntsen (2011) suggested that both types of memories were elicited throughout the day, but these data do not speak about more detailed moment-to-moment frequencies across the day. For example, the participants also reported that they primarily generated involuntary memories during periods of unfocused attention, boredom and daydreaming, whereas voluntary memories typically were generated when attention was more focused and there was a specific reason for remembering. This may suggest that the relative frequencies of the two types of memories vary over the day as a result of variations in daily activities and the amount of attention required accomplishing them.

In the present series of studies, we use a smartphone version of an electronic diary, which automatically registers the time of retrieval, thereby allowing us to obtain unique data on the temporal distribution of both involuntary and voluntary memories over the course of a day. Smartphone technology or related types of experiences sampling techniques have been frequently used in research involving on-line recordings of mind wandering (e.g., Kane, Brown, McVay,

Silvia, Myin-Germeys & Kwapil, 2007; Killingsworth & Gilbert, 2010; Poterio, Totterness & Miles, 2013) as well as in research on the distribution of mood, rumination and emotion in daily life (e.g., Diener & Tay, 2014; Marco & Suls, 1993; Moberly & Watkins, 2008; Nisenbaum, Links, Eyan & Heisel, 2010; Zelanski & Larsen, 2000).

Functional Differences Between Involuntary and Voluntary Memories

According to a dominant theory, autobiographical memory serves three broad functions: Directive, self, and social (e.g., Bluck, Alea, Habermas & Rubin, 2005; Cohen, 1998; Pillemer, 1992). The directive function refers to memories that guide future thinking and behavior, thereby assisting the individual in problem solving, decision making, and goal achievement (e.g., Pillemer, 2003). The self-function involves memories that inform the person as to who he or she is as an individual and remind the person of his or her beliefs and values. In addition, emotional regulation is sometimes regarded as a self-function (Bluck et al., 2005; but see Harris, Rasmussen & Berntsen, 2014). The social function concerns memories that are shared in conversation, for instance, to increase social bonding or communicate interest in or empathy with another person (e.g., Pillemer, 1992) or memories that you think of in order to increase intimacy in a relationship (e.g., Alea & Bluck, 2007).

One potential limitation of the tripartite model is that people may not be able to assess accurately what functions their memories serve (Hyman & Faries, 1992). This inability may apply to involuntary memories in particular, because these memories come to mind with no conscious initiation of the retrieval process. Instead, they are facilitated by a distinct feature overlap between the situational context and the memory content (e.g., Berntsen, 2009). In contrast, voluntary memories by definition are consciously initiated and generated with a specific purpose in mind. Accordingly, their functions most likely are more easily identified and assessed by the person,

especially if the estimates are taken immediately after retrieval. In addition, not all memories that come to mind involuntarily may serve a specific function in relation to the ongoing situation. They may simply pop up during periods of daydreaming, boredom or self-entertainment. However, this does not preclude other adaptive values such as providing a sense of continuity across time (Rasmussen & Berntsen, 2009b) or facilitating selective rehearsal and updating of autobiographical knowledge (Berntsen, 2012). In Studies 1 and 2, we ask the participants to assess retrospectively whether their memories served the three theoretical functions as well as such “non-instrumental” reasons for remembering.

Apart from Rasmussen and Berntsen (2011) only two studies have examined the functions of involuntary autobiographical memories, and only one of these involved a comparison with voluntary memories. Rasmussen, Johannessen and Berntsen (2014) compared naturalistic involuntary and voluntary memories using a structured diary method. The participants filled in two consecutive diaries (one for involuntary and one for voluntary memories) in randomized order. They recorded the first two of the assigned kind of memories that possibly came to mind each day and continued the recording for an extended period of time until they had recorded a total of 15 memories (Berntsen, 1996). The operational definitions of the two types of memories that were used for the instructions of the participants were similar to the ones used by Rasmussen and Berntsen (2011), but the ratings of the functions of the memories were accomplished on-line immediately after retrieval instead of retrospectively at the end of the day, and involuntary and voluntary memories were compared within instead of between subjects. Consistent with the retrospective ratings in Rasmussen and Berntsen (2011), participants in Rasmussen et al.’s diary study rated voluntary memories as serving more directive (i.e., behavior guiding and problem solving) and social sharing functions, whereas no differences with regard to self-functions were found. Also consistent with Rasmussen and Berntsen (2011), both types of memories displayed a

dominance of positive events (e.g., Walker et al., 2003; see also Walker & Skowronski, 2009), which speaks against the idea that involuntary memories are a sign of dysfunction and emotional distress (e.g., Brewin et al., 1996). Contrary to the retrospective assessment in Rasmussen and Berntsen (2011), there were no differences between involuntary and voluntary memories with regard to the on-line assessment of state of concentration at time of retrieval.

Kamiya (2014) found that participants experienced approximately 12 involuntary memories per hour and reported that most of these memories served self-functions, whereas the directive (i.e., problem solving) and social functions were reported less frequently. However, this study used a different method (i.e., “the field interview task”, as introduced by Kamiya, 2014), where participants walked around the university campus for approximately an hour with the experimenter walking closely behind them, and were instructed to report to the experimenter whenever they experienced an involuntary memory. Hence, these memories were not collected as they occur naturalistically in the flow of daily activities, and it is possible that the close presence of the experimenter may have inflated the frequency estimates. Furthermore, voluntary memories were not recorded. Kamiya (2014) reported a correlation between the frequency of involuntary memories and a measure of self-reported cognitive failures in everyday memory. This can be seen as consistent with previous findings of a relationship between involuntary memory frequency and individual differences in dissociation (Brewin & Soni, 2011; Hall & Berntsen, 2008) as well as with studies showing that involuntary memories predominantly come to mind when attention is unfocused (e.g., Berntsen, 1998; Berntsen & Jacobsen, 2008; Schlagman, Kvavilashvili & Schultz, 2007). These results may further suggest that some of the individual differences regarding memory frequency partly reflect individual differences in the ability to keep the mind focused when engaging in a task that requires close self-monitoring of mental processes. In addition, frequency estimates may also

be affected by individual differences in the ability to recognize involuntary memories (Mace, Bernas & Clevinger, 2014).

In summary, frequency estimates of involuntary autobiographical memories appear to be highly sensitive to slight changes in methodology, whereas ratings of emotional valence and perceived functions are more robust and replicate across studies. Reports of concentration at time of retrieval may be dependent on whether the ratings were given on-line or retrospectively.

Overview of the Studies

In the present series of studies, we examine the frequency and function of involuntary memories using a combination of on-line and retrospective methods. In Study 1, we attempt to replicate Rasmussen and Berntsen's (2011) findings that involuntary memories are approximately three times as frequent as their voluntary counterparts over the course of a day when using a mechanical counter to obtain on-line frequency estimates and a retrospective questionnaire filled out by the participants at the end of the day to address concentration, temporal distribution, emotional valence, cue type and perceived function generalized across all memories. In Study 2, we extend these findings with on-line smartphone ratings of the frequency and temporal distribution of involuntary and voluntary memories across the day in addition to the retrospective ratings used in Study 1. In Study 3, we eliminate retrospective measures and use the smartphones to assess all relevant variables on-line immediately after retrieval, thereby building onto the first two studies. Finally, in Study 4 we reanalyze the data from the preceding studies as well as Rasmussen and Berntsen (2011) in order to compare how the frequency estimates vary across the recording methods.

Study 1

The aim of Study 1 was to replicate Rasmussen and Berntsen (2011). Hence, using a mechanical counter we expected to replicate the finding that involuntary memories are approximately three times as frequent as their voluntary counterparts. Furthermore, when assessed retrospectively, we expected voluntary as compared to involuntary memories to be associated with problem solving and social sharing functions, whereas involuntary memories were expected to be associated with periods of boredom, daydreaming, no reasons for remembering, as well as less focused attention at time of retrieval. Finally, we expected no differences between the two types of retrieval with regard to self-functions (i.e., emotional regulation, identity; beliefs and values), cue type, emotional valence and temporal distribution.

Method

Participants. Fifty undergraduates were randomly allocated to the two conditions, balanced across age and gender, as closely as possible to Rasmussen and Berntsen (2011). As in Rasmussen and Berntsen (2011), there were 25 participants in the voluntary condition (20 females, mean age 22.52 years, SD = 2.31, range 21-31 years) and 25 in the involuntary condition (20 females, mean age 22.72, SD = 2.39, range 20-33). They each received two movie tickets in return for their participation.

Materials.

Mechanical counter. The participants were equipped with a mechanical counter in order to assist them in keeping track of the number of involuntary/voluntary memories. The mechanical counter (www.elektronik-lavpris.dk/product_info.php?products_id=96168; product number: BN204041) is a thumb or finger-actuated counter that fits in the palm of a hand. It is lightweight

(80 g.) and compact and easy to carry around, making it very convenient for simple counting with minimal distraction on co-occurring activities.

Questionnaire. The questionnaire to be answered retrospectively addressed all involuntary/voluntary memories that had occurred during the day. For Questions 1, 2 and 4, the participants were asked to choose just one of the response options, whereas for Question 3, they were allowed to choose more than one option: Question 1 addressing type of cue was: *“Did anything in your surroundings or in your thoughts typically seem to trigger the involuntary/voluntary memories?”* The response options were: something external, something internal, something both external and internal, or none of the above. Question 2 addressing temporal distribution was: *At what time of the day did the involuntary/voluntary memories typically occur?* The response options were: In the morning, in the afternoon, in the evening, or all day. Question 3 addressed the perceived function of the recall: *What do you think typically caused you to have the involuntary/voluntary memories?* The response options were: Problem solving (“I was solving a problem”), decision making (“I was making a decision”), establish/achieve goal (I wanted to establish or achieve a goal”), emotional regulation (“I was trying to make myself feel better”), identity (“I was reminding myself of who I am as an individual”), beliefs and values (“I was reminding myself of my believes and values”), share with person (“I wanted to share the memory with another person”), think about person (“I was reminding myself of another person”), show interest in person (“I wanted to show interest in another person”), boredom (“I was bored”), daydreaming (“I was daydreaming”), entertain myself (“I was entertaining myself”), no reason for remembering (“There was no specific reason”), and other (“other – please specify”). Question 4 that addressed emotional valence was: *With what kind of emotion did the involuntary/voluntary memories typically come?* The answer categories were: Positive emotion, negative emotion, both positive and negative emotion, or none of the above. Finally, Question 5 addressing the

participant's concentration level at retrieval was: *The involuntary/voluntary memories typically came in situations, where I was highly concentrated.* This question was measured on a 5 point Likert scale (1 = Not at all; 5 = to a high degree).

Response options for the questions addressing the perceived functions (Question 3) could be divided into conceptually meaningful subcategories. Specifically, the response options for problem solving, decision making, and establish/achieve goal addressed the directive function. The response options for emotional regulation, identity and beliefs, and values addressed the self-function. The response options for share with person, think about person, and show interest in person addressed the social function. Finally, the response options for boredom, daydreaming, and entertainment addressed "non-instrumental" reasons for remembering. Due to the low number of items per function as well as the low response rate on some of the options, a reliable composite score of the three functions could not be constructed. We return to this point in the general discussion.

Procedure. Both verbal and written instructions were provided. The participants were instructed individually in a laboratory setting by three trained graduate level research assistants. Using a between-subject design, some participants were informed that they were to record the frequency of their voluntary memories, whereas other participants were instructed to record their involuntary memories during a normal day in their lives. Participants were instructed to perform the task on the following day, or if that was not possible (for instance if they were going to an exam or planned to drink alcohol) they were instructed to choose the first coming possible day. They were presented with the mechanical counter, a one page questionnaire to fill out by the end of the day, and written instructions to take home.

An involuntary memory was defined as a memory about a past event that is brought to consciousness with no preceding conscious attempts at retrieval. Involuntary memories could be

cued by the present surroundings or aspects of current thought as long as the association in question had been established without intentional attempts. A voluntary memory was defined as a memory retrieved in a goal-directed and controlled manner. It was emphasized that the memory did not simply pop up by itself. Its retrieval had to be initiated consciously and in an intentional fashion in order for it to be considered a voluntary memory. Both types of memories were illustrated by similar examples in which only the retrieval process, not the memory content, differed. The participants were instructed to press the button on the mechanical counter each time they had an involuntary/voluntary memory, and make a note of the final number by the end of the day, at which point they were also instructed to fill out the one-page questionnaire addressing all the involuntary/voluntary memories that had occurred during the day. For both conditions, the participants were instructed to include all memories, regardless of their age, emotional valence, amount of rehearsal or level of importance. It was stressed that the memories had to be autobiographical and specific, that is, dealing with a personally experienced event that took place on a specific day in the person's past.

Results

We first report the findings regarding the on-line frequency measures, next we report the findings concerning the retrospective assessments.

On-line frequency. Initial analyses for frequency were conducted with the arithmetic mean as well as the square root transformation of the mean. Since both analyses showed similar results, we report the arithmetic mean. Consistent with Rasmussen and Berntsen (2011), involuntary memories were reported roughly 2.5 times as frequently ($M = 19.88$, $SD = 17.46$) as their voluntary counterparts ($M = 8.00$, $SD = 6.99$; $t = 3.16$, $p < .005$, $d = .89$; 95 % CI [4.21, 19.55]).

Retrospective assessments. Two participants reported no memories in the involuntary condition, precluding their completing the retrospective questionnaires. All other participants completed the questionnaire. According to the retrospective assessments, the voluntary memories occurred in situations in which the person was more concentrated ($M = 3.28$, $SD = .79$) as compared to the involuntary memories ($M = 2.39$, $SD = 1.03$; $t = 3.36$, $p < .005$, $d = .97$; 95 % CI [-1.42, -0.36]). There were no significant differences between the two retrieval types with regard to cue type, emotional valence, or the time of day of recording. That is, the participants reported that both types of memories happened throughout the day, were cued by both internal and external cues, and could be emotionally positive as well as emotionally negative.

The results addressing function are shown in Table 1. Notice that each participant was permitted to choose more than one function. As shown in Table 1, voluntary as compared to involuntary recall was more associated with problem solving and social sharing functions, whereas involuntary recall more frequently happened with no reasons for remembering. There were no differences between the two types of memories with respect to self-functions (i.e., emotional regulation, identity; beliefs and values). These results agree with Rasmussen and Berntsen (2011). In contrast to Rasmussen and Berntsen (2011), voluntary as compared to involuntary recall also was more strongly associated with establish/goal, whereas there were no differences between involuntary and voluntary recall with respect to daydreaming and boredom in the present study.

Discussion

The present study replicated the findings from Rasmussen and Berntsen (2011) using a mechanical counter as a way of obtaining a measure of the frequencies of involuntary and voluntary autobiographical memories during a normal day in the participants' lives. One potential limitation of Study 1 is that the mechanical counter only provides an on-line assessment of frequency, whereas

the other variables were assessed retrospectively. In Study 2, we therefore use the same design as in Study 1, but instead of the mechanical counter method, we utilize smartphones to assess the frequency and temporal distribution of involuntary and voluntary memories. The smartphone has the advantage that it automatically registers the time and date for each memory recording, thereby providing objective data on the temporal distribution of the memory records across the day, at the same time as obtaining frequency estimates.

Study 2

In Study 2, we used the same method as in Study 1 with the exception that the participants were equipped with a smartphone instead of a mechanical counter in order to assist them in keeping track of the number of involuntary/voluntary memories. Hence, on the basis of the cumulative findings from Study 1, as well as from Rasmussen and Berntsen (2011), we expected the involuntary memories to be approximately two to three times as frequent as their voluntary counterparts. Furthermore, when assessed retrospectively, we expected voluntary as compared to involuntary memories to be more associated with problem solving and social sharing functions, whereas involuntary memories were expected to be more associated with no reasons for remembering as well as with less focused attention at time of retrieval. Finally, we expected no differences between the two types of retrieval with regard to self-functions (emotional regulation, identity, beliefs and values), cue type, emotional valence and temporal distribution.

Method

Participants. As in Study 1, 50 undergraduates were randomly allocated to the two conditions (voluntary and involuntary memory report), balanced across age and gender. There were 25 participants in the voluntary condition (20 females, mean age 22.24 years, SD = 3.43, range 20-

37 years) and 25 in the involuntary condition (20 females, mean age 22.80, SD = 5.38, range 20-47). They each received two movie tickets in return for their participation.

Materials. The participants were equipped with a smartphone of the type HTC Wildfire running an android operating system (version 2.2; http://en.wikipedia.org/wiki/HTC_Wildfire) in order to assist them in keeping track of the number of involuntary/voluntary memories. The smartphone was programmed with an android survey app (i.e., SurveyToGo, www.dooblo.net) that enables creating, conducting, and managing of electronic mobile surveys.

Procedure. The procedure, design, and questionnaire were the same as in Study 1, with the exception that the participants were instructed to use a smartphone instead of a mechanical counter to count their memories. They were instructed to press a button on the smart phone each time they had an involuntary or voluntary memory, as appropriate to the condition assignment. Before and after pressing the button, they had to unlock and lock the smart phone, thereby potentially increasing the recording effort relative to the mechanical counter. We ensured that all participants were familiar with smartphone technology, for example, by checking that they currently owned a smartphone, or had owned one in the past. In addition, the participants were carefully instructed in the use of the smartphone and the SurveyToGo app. The SurveyToGo app on the smartphone registered the time and date of retrieval. The data were automatically uploaded to the SurveyToGo program via an Internet connection and later exported to SPSS. Finally, the number of iterations (i.e., the frequency of involuntary/voluntary memories) were noticed and entered into a SPSS-database. As in Study 1, the participants were instructed to answer the one page retrospective questionnaire addressing cue type, emotional valence, temporal distribution, perceived function and concentration at time of retrieval at the end of the day after finishing the counting task.

Results

As in Study 1, we first report the measures that were obtained on-line, that is, frequency of records and their time of occurrence. We next report the retrospective assessments.

On-line recordings. As in Study 1, initial analyses for frequency were conducted with the arithmetic mean as well as the square root transformation of the mean. Again, because both analyses showed similar results, we report the arithmetic mean. In contrast to previous findings, involuntary memories were not reported significantly more frequently ($M = 14.72$, $SD = 8.68$) than their voluntary counterparts ($M = 10.32$, $SD = 7.85$), although there was a non-significant statistical trend in the expected direction ($t = 1.88$, $p = .066$, $d = .53$; 95 % CI [-0.31, 9.11]) as well as a moderate effect size (Cohen, 1988).

In order to investigate the temporal distribution of involuntary and voluntary memories across the day based on the on-line recording from the smartphone, we plotted the percentage of involuntary and voluntary memories across participants as a function of the time of the day at which they were recorded. Figure 1 shows the relative frequency distribution divided into four hour time slots. As shown by the figure, both involuntary and voluntary memories were distributed across the waking hours of the day (i.e., from approximately 7 a.m. to 11 p.m.), consistent with the retrospective ratings in Study 1 as well as in Rasmussen and Berntsen (2011). A closer inspection of Figure 1 suggested a dominance of involuntary relative to voluntary memories in the time slots from 11 a.m. to 7 p.m., whereas voluntary memories were evenly distributed across the day. Chi-square tests confirmed that the observed frequency distribution of involuntary memories in the time slots from 7 a.m. to 11 p.m. differed from an even distribution ($\chi^2(3) = 15.29$, $p < .002$; $N = 355$; Cramer's $\nu = .208$), whereas this was not the case for voluntary memories in these time slots ($\chi^2(3) = .18$, $p = .98$; $N = 234$; Cramer's $\nu = .028$).

Retrospective assessments. One participant in each condition reported no memories and therefore did not complete the retrospective questionnaire. All other participants completed the questionnaire. As in Study 1, voluntary memories were retrospectively reported as occurring more often in situations in which the person was concentrated ($M = 3.09$, $SD = 1.08$) compared with involuntary memories ($M = 1.96$, $SD = .81$; $t = 4.04$, $p < .0005$, $d = 1.18$; 95 % CI [0.56, 1.69]). Also consistent with Study 1, as well as with Rasmussen and Berntsen (2011), there were no significant differences between the two retrieval types with regard to the retrospective assessments of cue type, time of day, and emotional valence.

The results for perceived function are shown in Table 2. In agreement with Rasmussen and Berntsen (2011) as well as Study 1, voluntary as compared with involuntary recall was more associated with problem solving, whereas involuntary recall was more associated with boredom, which Rasmussen and Berntsen (2011) also found; however, this difference was not evident in Study 1. In contrast to Study 1, as well as Rasmussen and Berntsen (2011), we found no differences between involuntary and voluntary retrieval with respect to social sharing and no reasons for remembering. Also in contrast to Study 1, we found no differences between the two types of retrieval with respect to establish/achieve goal. However, voluntary relative to involuntary memories were reported as being more associated with decision making, which also belongs to the directive function category.

Discussion

In the present study we used smartphones to obtain on-line frequency estimates for the occurrence of involuntary and voluntary autobiographical memories. We did not replicate previous findings with respect to frequency, although there was a non-significant statistical trend in the expected direction. The main difference between the present and previous results is that the reported

frequency of involuntary memories was lower, whereas the reported frequency of voluntary memories was roughly comparable to that of Study 1 as well as to Rasmussen and Berntsen (2011).

The most likely explanation for this difference is the use of the smartphone instead of the mechanical counter to assess the number of memories. Compared with the mechanical counter, the smartphone is slightly less intuitive and convenient in use, because it has to be unlocked and locked, before and after recording a memory. It is possible that this additional recording effort could have increased the threshold for when an involuntary memory would be reported, simply because they are more frequent. In contrast, the reported frequency of voluntary memories should be less affected by task demands, because they happen less frequently and thus call for less recording effort overall. Thus, according to this explanation, the participants in the voluntary condition were likely to have been less affected by the added recording effort as compared with the participants in the involuntary condition.

The objective time data that were automatically registered by the smartphone each time a memory was reported showed that although both involuntary and voluntary memories happened frequently throughout the waking hours of the day, the involuntary memories were more dominant during the time period from 11 a.m. to 7 p.m. In contrast, the voluntary memories were evenly distributed across the day with no specific high points (see Figure 1). With regard to retrospective assessments of concentration at the time of retrieval, perceived function, type of cue, and emotional valence, the results largely replicated the findings of Study 1 and Rasmussen and Berntsen (2011), with the exception of minor differences for perceived function. The retrospective reports of time for retrieval suggested that both involuntary and voluntary memories were evenly distributed across the waking hours of the day and thus replicated the previous studies using similar retrospective assessments. Nevertheless, these findings were contradicted by the objective time data in the present study, which showed an even distribution only for voluntary memories.

Study 3

The aim of Study 2 was to examine whether we could replicate the frequency findings from Rasmussen and Berntsen (2011) as well as from Study 1, using a smartphone instead of a mechanical counter. The aim of Study 3 was to examine whether we could replicate the retrospective ratings of concentration, emotional valence, and perceived function found in Studies 1 and 2, when using on-line ratings on the smartphone instead of the retrospective questionnaire. In order to reduce the effect of the potentially added recording effort on the frequency estimates, we included only three questions to be rated immediately after each memory: Concentration, because this variable has displayed different results in previous studies depending on whether retrospective or on-line methodology has been applied (Rasmussen & Berntsen, 2011; Rasmussen et al., 2014; the present Studies 1 and 2); emotional valence, to enable analyses of the distribution of different categories of emotional memories across the day; and functional relevance, because this variable has shown consistent differences between the two retrieval types (Kamiya, 2014; Rasmussen & Berntsen, 2011; Rasmussen et al., 2014; the present Studies 1 and 2). Hence, the function categories in Studies 1 and 2 were reduced to one overarching question of functional relevance to the ongoing situation in order to minimize the potential effects on frequency.

Method

Participants. Sixty undergraduates were randomly assigned to the two conditions. We used a between-subject design in which we assigned 30 participants to the voluntary condition (24 females, mean age 23.23 years, SD = 2.43, range 21-31 years) and 30 participants to the involuntary condition (24 females, mean age 24.43, SD = 7.86, range 20-63). Each participant received two movie tickets in exchange for their participation.

Procedure. The procedure was the same as in Study 2, with the exception that the participants were instructed to answer three rating scale questions immediately after each memory. Thus, in contrast to Studies 1 and 2, no retrospective ratings were used. After pressing the button to indicate an involuntary or voluntary memory, the three rating scale questions would appear on the screen of the smart phone one at the time. Question 1 addressing concentration was: *The memory came in a situation, where I was highly concentrated* (1 = very unconcentrated; 5 = very concentrated). Question 2 addressing valence was: *The feelings I experience as I recall the event are* (-2 = very negative; 0 = neutral; 2 = very positive). Question 3 addressing relevance was: *The memory was relevant to my current situation when it came* (1 = not at all; 5 = to a high degree). As in Study 2, the data were automatically uploaded to the SurveyToGo program and exported to SPSS. Again, the number of iterations (i.e., the frequency of involuntary/voluntary memories) were noticed and entered into a final SPSS-database. Because data from the three rating scale questions consisted of multiple observations from each of the 60 participants, we calculated an average score for concentration, relevance, and valence across the total number memories for each participant, and entered the scores into the final database. Due to the setup of the SurveyToGo app, it was not possible for the participants to skip a question before moving on to the next.

Results

One participant in the voluntary condition reported no memories at all, which precluded answering the three rating scale questions. All other participants answered the rating scale questions. As in Studies 1 and 2, only minor differences were found between the arithmetic and the square root transformation of the mean for frequency, so we report the arithmetic mean. The means and standard deviations as well as the results from a *t*-test are presented in Table 3. In contrast to previous studies, there was no significant difference between the reported frequencies of

involuntary and voluntary memories. As in Study 2, we plotted the percentages of involuntary and voluntary memories across participants as a function of the time of the day at which they were recorded. Figure 2 shows the relative frequency distribution divided into four hour time slots. As shown in the figure, the number of both involuntary and voluntary memories were distributed across the waking hours of the day (i.e., from approximately 7 a.m. to 11 p.m.), in accordance with the findings from Study 2 (see Figure 1). A visual inspection of Figure 2 suggested a dominance of involuntary relative to voluntary memories in the time slots from 7 a.m. to 3 p.m., whereas voluntary memories were more evenly distributed across the day. Chi-square test showed that involuntary memories tended to be unevenly distributed across the time slots from 7 a.m. to 11 p.m. although only a non-significant statistical trend was seen ($\chi^2(3) = 6.45, p = .09; N = 340$; Cramer's $\nu = .138$). Consistent with Study 2, there were no differences between the observed and expected frequencies for voluntary memories in these time slots ($\chi^2(3) = 1.63, p = .65; N = 251$; Cramer's $\nu = .081$).

As shown by the mean values in Table 3, voluntary memories were rated as having more functional relevance to the current situation than involuntary memories, consistent with Studies 1 and 2. There was no difference between the two types of retrieval with respect to the level of concentration, when rated at time of retrieval, suggesting that ratings of this variable were affected differently by on-line assessments (in the present study) versus retrospective assessments (in Studies 1 and 2), in agreement with previous findings (Rasmussen & Berntsen, 2011; Rasmussen et al., 2014). Finally, consistent with findings from diary studies (e.g., Berntsen, 2009 for a review) as well as retrospective ratings (Studies 1 and 2; Rasmussen & Berntsen, 2011), there were no differences between involuntary and voluntary memories with respect to their mean ratings on emotional valence.

In order to further investigate the interplay between retrieval type, time of day, and emotional valence, we recoded the ratings for emotional valence into three new categories (positive, 1-2; negative, -1-(-2), and neutral, 0) and plotted the percentages of these categories as a function of the temporal distribution across the day in four hour time slots. Figure 3 depicts the relative frequencies for voluntary memories in the top panel and for involuntary memories in the bottom panel. As shown by the figure, there was a dominance of positive relative to negative memories in most time slots for both types of retrieval, consistent with previous findings for both involuntary and voluntary memories (e.g., Berntsen, 1998) and for autobiographical memory in general (e.g., Walker et al., 2003). Contrary to previous findings (Rasmussen et al., 2014), there was an overrepresentation of neutral (or mixed) memories for voluntary, but not for involuntary memories in the present study. This interplay between valence and type of retrieval was further confirmed by a chi-square test ($\chi^2(2) = 16.60, p < .0005; N = 646; \text{Cramer's } \nu = .161$).

Discussion

In Study 3, we again used smartphones to obtain on-line frequency estimates for the occurrence of involuntary and voluntary autobiographical memories. Furthermore, we added three questions addressing concentration, emotional valence, and perceived functional relevance to be rated on-line after each memory occurrence in contrast to previous work, in which these measures were obtained retrospectively. As in Study 2, but contrary to findings in studies using a mechanical counter, the frequency of involuntary and voluntary memories did not differ significantly. This suggests that the three rating scale questions after each memory instance, in addition to the use of the smartphone instead of a mechanical counter, may have increased the recording effort and thus reduced the number of involuntary memories. As in Studies 1 and 2, the reported frequency of voluntary memories was roughly comparable to that of Rasmussen and Berntsen (2011), in

agreement with the idea that the extra recording effort in Study 2 and in the present study may have influenced the threshold for when an involuntary memory is reported, whereas the reporting of voluntary memories was not affected, presumably because they are less frequent. Contrary to Rasmussen and Berntsen (2011), but consistent with Rasmussen et al. (2014), who also assessed concentration on-line immediately after retrieval, in the present study we found no difference between the two types of memories with respect to the ratings of concentration at time of retrieval. This question addressed whether the person was concentrated on a certain task (e.g., reading) when the memory occurred, but participants may, instead, have perceived the question as an index of retrieval effort. If so, it is possible that the extra recording effort associated with the smartphone may have increased the perceived level of concentration at the time of recording. Logically, this could potentially increase the concentration ratings for involuntary but not for voluntary memories, simply because the level of concentration for a voluntary memory search already was elevated relative to that of an involuntarily retrieved memory. Voluntary as compared with involuntary memories were perceived as being more relevant to the current situation, in accordance with previous work using retrospective assessment (i.e., Studies 1 and 2 as well as Rasmussen and Berntsen, 2011). Moreover, as found earlier, there were no differences between the two types of retrieval with regard to their mean ratings on emotional valence.

The temporal distribution data concurred with previous work showing that the recordings of both involuntary and voluntary memories were distributed throughout the waking hours of the day (i.e., in the time slots from 7 a.m. to 11 p.m.). Compared to Study 2, the overrepresentation of involuntary memories in certain time slots were a bit earlier in the day, less marked, and did not reach the threshold for statistical significance, although a non-significant trend was seen ($p = .09$). However, this may be due to the general decrease in the number of involuntary memories in the present study relative to Study 2. Further examination of the temporal distribution of emotionally

positive, neutral, and negative memories across retrieval types showed no differences in the overall distribution, but positive as compared to negative memories generally were more frequent, whereas voluntary memories, more frequently than their involuntary counterparts, were associated with neutral emotion.

Study 4: A Meta-analysis to compare Frequency across Methods

The first three studies suggest that the frequency of involuntary autobiographical memories varies according to the recording methods, whereas variability seems to be a lesser problem for frequency estimates of naturally occurring voluntary autobiographical memories. Study 1 in the present series and Rasmussen and Berntsen (2011) suggest that involuntary autobiographical memories are 2.5 to 3 times as frequent as their voluntary counterparts, when participants use a mechanical counter to keep track of the memories ($ds > .88$). Findings from Studies 2 and 3 suggest that this difference becomes statistically non-significant if the participants use a smart phone to assist them in keeping track of the memories ($ds < .54$), although a non-significant trend in the expected direction was found in Study 2 ($p = .066$). We explained this finding as an effect of the latter method entailing more recording effort than the former, which would affect the frequency estimates of involuntary – but not of voluntary memories – simply because the former overall is more frequent. In order to examine this possibility more carefully, we compared the findings from Rasmussen and Berntsen (2011; for details) with the present Studies 1, 2 and 3. A 2 (retrieval type: involuntary/voluntary) by 4 (method: R&B, 2011/Study 1/Study2/Study3) univariate ANOVA showed a significant main effect for retrieval type ($F(1, 207) = 33.03, p < .0005, \eta_p^2 = .14$) reflecting the findings that involuntary memories overall were more frequent as well as a significant interaction ($F(3, 621) = 3.65, p < .05, \eta_p^2 = .05$). As shown by Figure 4, the interaction was largely due to the reduction in frequency of involuntary – but not in voluntary – retrieval with increasing

demands imposed by the recording procedure. A posthoc t-test showed that there tended to be a statistically non-significant difference between the frequency estimates of involuntary memories in the two extreme cases (i.e., Rasmussen & Berntsen, 2011 and the present Study 3; $p = .07$, see Figure 4). Such a tendency was not seen in the voluntary condition.

General Discussion

We have shown that the frequency of involuntary autobiographical memories is sensitive to differences between on-line recording methods and their associated levels of effort, whereas the frequency of voluntary memories was stable across studies. In addition, on-line versus retrospective assessment methods yielded different results for measures of concentration at time of retrieval, whereas the ratings for emotional valence, temporal distribution and perceived functional relevance were less affected.

With regard to the frequency findings, our results are in line with previous work showing that involuntary memories are at least as frequent as their voluntary counterparts and almost three times as frequent when assessed on-line with a mechanical counter (e.g., Rasmussen & Berntsen, 2011). However, the on-line smartphone assessment of frequency in Studies 2 and 3 did not show the expected dominance of involuntary memories. This might be seen to support the retrospective assessments in Rubin and Berntsen's (2009) large survey study showing no or very little differences between the two forms of remembering. Alternatively, we have argued that this difference was due to the smartphone entailing more recording effort in the present studies 2 and 3. This may have affected the frequency estimates for involuntary relative to voluntary memories, simply because the former occur more frequently and therefore are compromised more by increased levels of recording effort, whereas the corresponding frequency measures of voluntary memories should be less affected because they occur less frequently. If this latter explanation is valid, we would expect that

an additional increase in recording effort – such as for instance an increase in the number of questions to be answered after each memory – at some point also would affect the frequency of voluntary memory records.

The findings for temporal distributions across the day were based on retrospective assessment in Study 1 and on-line assessments in Studies 2 and 3. The results agreed with previous work with retrospective as well as on-line assessment (Rasmussen & Berntsen, 2011; Rasmussen et al., 2014), showing that both types of retrieval were distributed throughout the waking hours of the day. However, the on-line ratings from the smartphones further highlighted that involuntary, as compared to voluntary memories, were more frequent in the middle of the day, whereas voluntary memories were more evenly distributed across the day. This difference was numerically present but did not reach the threshold for statistical significance in Study 3, but this was most likely due to the general decrease in the number of involuntary as compared to voluntary memories in this study.

In accordance with most previous work (Rasmussen & Berntsen, 2011), the findings for concentration at time of retrieval showed that involuntary, as compared to voluntary retrieval, was more associated with unfocused attention in Studies 1 and 2, in which retrospective assessment was employed. However, the on-line smartphone ratings from Study 3 showed no difference between the two types of retrieval, consistent with one previous diary study, which also utilized on-line assessment of concentration for both types of memories (i.e., Rasmussen et al., 2014). It is possible that people are unable to accurately assess their concentration levels retrospectively, or that participants answered this question on the basis of the level of concentration associated with the recording and not on the basis of the actual concentration level at the time of retrieval. Future studies should aim at examining these possible explanations.

The findings regarding emotional valence and perceived functional relevance were consistent across the three studies, suggesting that these variables are less sensitive to differences

between on-line and retrospective measuring. Across all three studies, voluntary as compared to involuntary memories were perceived as being more functionally relevant to the ongoing situation, especially regarding directive functions (problem solving in Studies 1 and 2, establish/achieve goal in Study 1 and decision making in Study 2), in accordance with previous studies (Rasmussen & Berntsen, 2011; Rasmussen et al., 2014). These findings appear to be a natural consequence of the fact that the voluntary memories follow a conscious intention and effort to access a memory. Normally, this would be done in situations with a specific need for it. Involuntary memories on the other hand typically arise as a consequence of a distinct feature overlap between the memory and the ongoing situation (Berntsen, Staugaard & Sørensen, 2013). Such overlap maximizes the likelihood of relevance to the ongoing situation, but it still is not as selective as the controlled retrieval processes generating voluntary memories. These findings may suggest that the more advanced and controlled voluntary retrieval primarily takes over in situations, when involuntary retrieval has failed to provide the relevant information, whereas the adaptive value of the involuntary memories often may extend beyond immediate instrumental relevance to the ongoing situation, for example, in terms of mood regulation, automatic updating of autobiographical knowledge and selective rehearsal of past events (e.g., Berntsen, 2009; 2012; Rasmussen & Berntsen, 2009b; 2011). The on-line smartphone ratings from Study 3 replicated the dominance of positive events for both involuntary and voluntary retrieval (e.g., Berntsen, 2010; Rasmussen & Berntsen, 2011; Walker et al., 2003; Watson et al., 2012), but in addition we found a dominance for neutral memories in the present voluntary condition, which was not found by Rasmussen et al (2014), who also compared naturalistic voluntary and involuntary memories – albeit with a different method.

One limitation of the present meta-analysis presented as Study 4 is that the participants were not randomly assigned to the different recording conditions. Conducting all three studies as a single

experiment with such randomization would have been optimal had our aim been to simply compare the effects of different recording methods on frequency estimates. However, the primary aim of the present series of studies was to achieve a better understanding of the frequency and function of involuntary as compared to voluntary memories. The present work was not designed as an experiment on the effects of recording methods *per se*. Although conclusions from the meta-analysis should be drawn with this caveat in mind, it should be noted that the samples present across the three studies were very homogenous, and that the instructions were the same, except for those directly related to the recording procedures.

Another potential limitation might be the use of a self-caught (or self-classification) version of the experience sampling method across the three studies rather than a probe-caught method (e.g., Kane et al., 2007), where participants are signaled randomly across the day and asked to report their mind content immediately after they are signaled. Researchers have argued that self-monitoring may encourage participants to assign an artificially high attention to their awareness, which may potentially overestimate the mental phenomenon of interest (e.g., Giambra, 1995). However, if this were the case, it should not affect our conclusions, since we would logically expect involuntary and voluntary memories to be similarly affected by the self-monitoring procedure. Furthermore, self-monitoring does not appreciably alter the phenomenological experience of mind wandering episodes (Smallwood & Schooler, 2006), so it seems plausible that this may also hold for involuntary and voluntary recall (see Rasmussen & Berntsen, 2011, for a discussion of this issue). The self-caught sampling technique was selected for the present studies due to the observation that involuntary and voluntary memories probably are not sufficiently frequent to be picked up by regular probes, unless participants were probed at least every minute, given the average frequency of roughly 10-20 memories per day. Obviously, such frequent probing would cause major disruptions in daily life and render the ensuing results highly questionable. The self-classification

method therefore seems to be the most appropriate on-line sampling measure for involuntary as well as voluntary autobiographical memories in daily life.

An additional limitation of the present studies is the relatively small samples sizes. However, these were based on the large effects (2-3 times as many involuntary as compared to voluntary memories; $d_s > .88$) found in Study 1 as well as in Rasmussen and Berntsen (2011) in spite of the relatively small number of participants in these studies. Small sample sizes may increase the risk of Type II errors. It is thus possible that the non-significant differences that were seen in Studies 2 and 3 would have been statistically reliable differences with larger sample sizes. This idea was supported by the meta-analysis in Study 4, which we performed on the combined data from the present studies as well as data from Rasmussen and Berntsen (2011) - thus half of the participants based their frequency estimates on the mechanical counter; half on the smart phone. Based on this analysis, involuntary memories overall were more frequent than their voluntary counterparts, although this was qualified by an interaction with recording condition. Also, the present studies involved few male participants, which precluded systematic analyses of gender differences. In order to explore whether this had affected the results, we reran the meta-analysis reported in Study 4 with gender included as an additional factor. We found no gender effect; males and females had similar numbers of involuntary and voluntary memories, and involuntary memories were more frequent across the two genders. Nonetheless, additional research is needed to more systematically examine the generalizability of the reported findings to male participants.

A final limitation concerns the retrospective ratings of function in Studies 1 and 2. Due to the low number of items per function as well as the low response rate on some of the options (see Tables 1 and 2), a reliable composite score of the three functions could not be constructed. However, previous work has shown conflicting evidence in support of the tripartite model, and it remains unclear whether the three functions are too broad or whether other functions of

autobiographical memory may also exist (e.g., Harris et al., 2014; Rasmussen & Habermas, 2011; Webster, 2003 for further discussion). Nonetheless, the findings from the present studies 1 and 2 agree with previous work (Rasmussen & Berntsen, 2011; Rasmussen et al., 2014), suggesting that voluntary as compared to their involuntary counterparts serve more directive functions, in particular in terms of problem solving, as well as more social sharing functions, although this was only replicated in the present Study 1.

In conclusion, the present findings are in line with previous work suggesting that involuntary autobiographical remembering is an easy, but fleeting way, to access the personal past, which can be associated with positive as well as negative emotion and have adaptive values that operate differently from the less frequent and more selective voluntary autobiographical memories. Considered individually, involuntary memories often have no direct utility in relation to the ongoing situation, whereas voluntary memories serve clearer functions to the present situation – especially with respect to problem solving and overall behavior guidance.

The present findings also suggest that the observed frequency of involuntary memories is sensitive to the exact methods used to make the recordings. Therefore, precautions should be taken when measuring frequency is the principal research aim. First, on-line assessment is generally preferred to retrospective ratings, although on-line ratings are sensitive to even smaller changes in instructions and/or measurement devices. Second, if on-line assessment is selected, the measurement device should be as simple as possible, entailing a minimum of recording effort and interruption in the person's daily routine. The mechanical counter, such as the one used in the present Study 1 and in Rasmussen and Berntsen (2011) seems optimal, but a simple notebook has also proven successful in previous work (e.g., Finnbogadottir & Berntsen, 2013). Third, the recording period should be varied in order to investigate whether participants might report higher frequencies if the time interval for recording is shortened, as possibly suggested by Kamiya's

(2014) findings from the field interview task. Fourth, given the large variability in the frequencies of the on-line records of both involuntary and voluntary remembering here as well as in previous work (Finnbogadottir & Berntsen, 2013; Rasmussen & Berntsen, 2011), future research should examine the influence of individual differences such as personality, age, gender, executive function and depression on the frequency of naturally occurring involuntary and voluntary memories in daily life.

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Table 1

Percentage of Perceived Function for Involuntary and Voluntary Memories in Study 1 Using Mechanical Counters and Retrospective Questionnaires

Function category	Involuntary memories N = 23	Voluntary memories N = 25	Significance level (Fischer's exact test)	Cramer's v
Directive functions				
Problem solving	17.4	68.0	$p < .001$	.510
Decision making	4.3	20.0	ns	.236
Establish/Achieve goal	0.0	28.0	$p < .01$	.396
Self-functions				
Emotional regulation	0.0	8.0	ns	.200
Identity	21.7	4.0	ns	.268
Beliefs and values	4.3	8.0	ns	.075
Social functions				
Share with person	34.8	76.0	$p < .009$	.415
Think about person	30.4	28.0	ns	.027
Show interest in person	8.7	8.0	ns	.013
Non-instrumental functions				
Boredom	21.7	4.0	ns	.268
Daydreaming	52.2	28.0	ns	.247
Entertain myself	8.7	4.0	ns	.097
No reason	39.1	0.0	$p < .0005$	.501
Other	21.7	12.0	ns	.131

Note: The percentages are derived from the number of yes answers to a certain function. Each participant was permitted to choose more than one function.

Table 2

Percentage of Perceived Function for Involuntary and Voluntary Memories in Study 2 Using Smart Phones and Retrospective Questionnaires

Function category	Involuntary memories N = 24	Voluntary memories N = 24	Significance level (Fischer's exact test)	Cramer's v
Directive functions				
Problem solving	8.0	58.3	$p < .005$	.537
Decision making	8.0	37.5	$p < .02$	.354
Establish/Achieve goal	4.0	0.0	ns	.141
Self-functions				
Emotional regulation	12.0	4.2	ns	.143
Identity	12.0	4.2	ns	.143
Beliefs and values	4.0	8.3	ns	.090
Social functions				
Share with person	44.0	68.5	ns	.184
Think about person	28.0	28.0	ns	.013
Show interest in person	4.0	4.2	ns	.004
Non-instrumental functions				
Boredom	32.0	4.2	$p < .03$	.359
Daydreaming	64.0	45.8	ns	.183
Entertain myself	4.0	12.5	ns	.155
No reason	24.0	4.2	ns	.283
Other	28.0	25.0	ns	.034

Note: The percentages are derived from the number of yes answers to a certain function. Each participant was permitted to choose more than one function.

Table 3
Mean Values, Standard Deviations and Results from a t-test Comparing the Involuntary and Voluntary Memories in Study 3 Using Smart Phones

Memory variable	Involuntary memories		Voluntary memories		<i>t</i>	d	95 % CI
	N = 30		N = 29				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Frequency	12.40	10.17	9.13	6.58	1.48	.38	-1.16, 7.69
Concentration	2.77	.55	2.91	.58	-.95	.25	-0.43, 0.15
Valence	.18	.38	.23	.25	-.66	.16	-0.22, 0.11
Relevance	2.61	.72	3.08	.67	-2.63*	.68	-0.84, -0.11

Note: * $p < .02$

Figure 1. Percentage of Involuntary and Voluntary Memories across all Participants in Study 2 as a Function of the Time of the Day at which they were recorded

Figure 2. Percentage of Involuntary and Voluntary Memories across all Participants in Study 3 as a Function of the Time of the Day at which they were recorded

Figure 3. Percentages of Positive, Neutral and Negative Voluntary (top panel) and Involuntary Memories (bottom panel) in Study 3 as a Function of the Time of the Day at which they were recorded

Figure 4: Mean Ratings of Frequency of Involuntary and Voluntary Memories in Rasmussen and Berntsen (2011) and Studies 1-3. Error bars Denote Standard Error of the Mean.