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Remembering a nuclear accident in Japan: Did it trigger flashbulb memories?

Hajime Otani
Central Michigan University, Mount Pleasant, USA

Takashi Kusumi
Kyoto University, Japan

Koichi Kato
Central Michigan University, Mount Pleasant, USA

Ken Matsuda
Kyoto University, Japan

Rosalie P. Kern
Michigan Technological University, Houghton, USA

Robert Widner, Jr.
Minnesota State University Mankato, USA

Nobuo Ohta
Tsukuba University, Japan

Flashbulb memories are vivid memories of the details surrounding the discovery of an emotional event. We investigated whether the nuclear accident that occurred in Japan in 1999 produced flashbulb memories among people who lived near the accident site. A questionnaire was distributed twice (approximately 3 weeks after the accident and 1 year later) to (1) the residents of the communities surrounding the accident site, (2) the students at a university near the accident site, and (3) the students at two universities far away from the accident site. Flashbulb memory holders were defined as those individuals who showed consistent memories between test and retest. The results indicated that only a small percentage of participants formed flashbulb memories. Further, no age-related decline was found. Flashbulb memories were distinguished by perfect or near perfect scores on four attributes: source, place, activity, and people. The results also indicated that the ratings on emotional reactions, personal consequentiality, and surprise did not differentiate between the flashbulb and non-flashbulb memory holders. In contrast, the flashbulb memory holders reported rehearsing more than the non-flashbulb memory holders. These results supported the notion that flashbulb memories are formed through rehearsal rather than at encoding. However, it is also possible that rehearsal was a result of the flashbulb memory.

Correspondence should be addressed to Hajime Otani, Department of Psychology, Central Michigan University, Mount Pleasant, MI 48859, USA. Email: hajime.otani@cmich.edu

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On 30 September 1999, Japan experienced one of the worst nuclear accidents in its history. At about 10:30 a.m., three workers at the JCO company (located at Tokaimura, Ibaraki prefecture, approximately 90 km north of Tokyo) saw a flash of blue light bursting from a tank where they had just poured uranium for purification. After being rescued, one of the workers confessed that they dumped 16 kg of uranium into a tank that had the maximum limit of 2.4 kg, setting off an uncontrollable nuclear chain reaction. At about 11:45 a.m., the level of radioactivity in a nearby street measured more than 10,000 times above normal, and at 3:30 p.m., 161 residents who lived near the accident site were evacuated. Because the high level of radioactivity did not subside at nightfall, the governor of Ibaraki prefecture issued an order at 10:30 p.m. for 310,000 residents within 10 km radius of the accident site to stay indoors until further notice (*Mainichi INTERACTIVE*, 1999a). This order was rescinded at 4:30 p.m. the next day; however, by then, 49 people were exposed to harmful radiation (*Mainichi INTERACTIVE*, 1999c). A few months later, two of the workers died at the hospital (*Mainichi INTERACTIVE*, 1999d, 2000), and a year later, the number of individuals who were exposed to harmful radiation was reported to be 667 (Kaneda, 2000). What made this ordeal so terrifying was that the government was totally unprepared. On the night of 30 September, while workers at the JCO company were still trying to figure out how to contain the chain reaction, the government officials admitted that the nation was facing an unprecedented nuclear crisis (*Mainichi INTERACTIVE*, 1999b).

Past research has indicated that such an emotionally traumatic event can sometimes produce vivid memories of the details surrounding the event. In addition to remembering the event itself, people often report such details as when they heard the news, from whom they heard the news, whom they were with, what they were doing, etc. These memories were referred to as *flashbulb memories* by Brown and Kulik (1977). By investigating participants' memories of famous political assassinations (e.g., John F. Kennedy in 1963 and Martin Luther King in 1968), these researchers found that participants' accounts of these surprising historical events contained six canonical features: place, ongoing activity, informant, own affect, affect of others, and aftermath. Further, they found that the occurrence of flashbulb memories was greater among African American participants, relative to Caucasian participants, for the assassinations of individuals who were relevant to civil rights movements (Martin Luther King, Malcolm X, and George Wallace). Based on these results, Brown and Kulik proposed that when an event is *surprising* and *consequential*, a special physiological mechanism (the ''now print'' mechanism proposed by Livingston, 1967) preserves many of the details surrounding the event because remembering these details may be crucial for one's survival.

Since Brown and Kulik's (1977) seminal work, three issues have dominated the literature of flashbulb memories. Accuracy is one of the major issues because individuals often show high confidence in the accuracy of their flashbulb memories. However, the results have been mixed as to whether these memories are as accurate as they claim. For example, Neisser and Harsch (1992) reported surprisingly low accuracy of the memories surrounding the explosion of the space shuttle *Challenger* based on a questionnaire that was repeated twice, the morning after the disaster and approximately a year and a half later. Because the actual accuracy of these memories was impossible to assess, these researchers (along with other researchers in this field) defined accuracy as consistent responses between test and retest. The results showed that only 7% of participants achieved complete accuracy whereas 25% showed complete inaccuracy. Further, 50% of them showed accurate recollection on only one out of three major attributes that were tested (location, activity, and informant). Interestingly, despite such inaccuracy, participants' confidence levels were quite high.

Based on these results, Neisser and Harsch concluded that flashbulb memories can be ''appreciably less reliable than other cases of vivid and confident recall'' (1992, p. 30). Poor accuracy, even though not as dramatic, has been reported by Christianson (1989) who examined memories surrounding the assassination of the Swedish prime minister Mr Olof Palme, and McCloskey, Wible, and Cohen (1988) who examined memories surrounding the space shuttle *Challenger* disaster. However, contrary to these researchers, Conway et al. (1994) and Cohen, Conway, and Maylor (1994) reported a considerably higher percentage of participants forming accurate flashbulb memories. These researchers investigated memories surrounding the resignation of British prime minister Mrs Margaret Thatcher. Similar to Neisser and Harsch, they repeated their

questionnaire twice (within 10 to 14 days after the resignation and approximately 11 months later) in order to examine the consistency of participants' responses. Conway et al. reported that 86% of their participants in the United Kingdom formed accurate flashbulb memories, whereas Cohen et al. reported that 90% of young adults and 42% of older adults formed accurate flashbulb memories. These results suggest that flashbulb memories cannot be dismissed as completely illusory memories.

The second issue is whether a special mechanism is necessary to explain the formation of flashbulb memories. McCloskey et al. (1988) argued that a special mechanism is not necessary because, just like memories of regular events (i.e., autobiographical memories), flashbulb memories can be inaccurate and forgotten. These researchers reported that the responses on the second questionnaire, which was administered 9 months later, showed evidence of forgetting and inaccuracy. Further, over the 9-month period, for some questions, the specificity of responses changed from specific to general. Based on these results, McCloskey et al. disputed the strong claim of Brown and Kulik (1977) that flashbulb memories are accurate and immune to forgetting. McCloskey et al. argued that the mechanisms that are responsible for normal memories could also account for the formation of flashbulb memories. Weaver (1993) also reached a similar conclusion based on his comparison between a surprising event (the bombing of Iraq in 1991) and an event that was not surprising (a class assignment to interview a friend). He found that there was no difference in memories associated with these two events.

In contrast, other researchers have argued that the formation of flashbulb memories requires a special mechanism. Conway et al. (1994) pointed out that contrary to McCloskey et al.'s claim about the inaccuracy of flashbulb memories, 89% of participants in McCloskey et al.'s study actually showed consistent memories over the 9-month period. Further, Schmidt and Bohannon (1988) noted that McCloskey et al. did not measure the emotional reactions of the participants; thus, it is unknown whether those participants who did not show accurate flashbulb memories did indeed experience the emotional reactions necessary to develop flashbulb memories. In fact, studies have shown that affect (i.e., emotional reaction) is a crucial component for the formation of flashbulb memories. For instance, Bohannon and Symons (1992) conducted a 3-year follow-up study of Bohannon's (1988) space shuttle *Challenger* study. These researchers found that among the ''upset'' participants, there were more consistent memory holders than inconsistent memory holders. In contrast, the ''calm'' participants were evenly divided between the consistent and inconsistent memory holders. Based on these results, emotional involvement appears to distinguish flashbulb memories from autobiographical memories.

Conway et al. (1994) also concluded that the mechanism of forming flashbulb memories is different from the mechanism of forming autobiographical memories. They examined the causal structure of flashbulb and ordinary memories using structural equation modelling. They found that although similar processes were present in both flashbulb and non-flashbulb memories, there was a critical difference between the two, which was in how these processes interacted. For non-flashbulb memories, these processes work independently, whereas for flashbulb memories, these processes are coordinated. That is, although either importance or affect can create non-flashbulb memories, importance must influence affect to create flashbulb memories. Thus, Conway et al. believe that a different process is responsible for the formation of flashbulb memories. Finkenauer et al. (1998) supported this position. These researchers also created a structural equation model of flashbulb memory and argued that the mechanism responsible for the formation of flashbulb memories is different from the mechanism responsible for the formation of non-flashbulb memories even though the two forms of memories share some processes in common (e.g., encoding based on novelty and importance of an event).

The third major issue is what variables influence the formation of flashbulb memories. As mentioned earlier, Brown and Kulik (1977) proposed surprise and consequentiality to be the two components that are necessary for the formation of flashbulb memories. Further, they identified rehearsal as a variable that enhances the completeness of flashbulb memories. These variables have received wide support (Finkenauer et al., 1998). In addition, Conway et al. (1994) identified knowledge/interests as a critical variable. Based on their structural equation model, knowledge/interests influences importance which, in turn, influences affect to create flashbulb memories. However, Finkenauer et al. (1998) did not find

importance and affect to be critical factors. In their study, they compared three models based on the data they gathered about the memories surrounding the death of the Belgian king, Baudouin. The three models were (1) Brown and Kulik's (1977) model, which they referred to as the *photographic* model, (2) Conway et al.'s (1994) model, which they referred to as the *comprehensive* model, and (3) their own model, which they referred to as the *emotional-integrative* model. The results indicated that the emotional-integrative model, which proposes two paths leading to the formation of flashbulb memories, provided a closer fit to the data than the other models. The first path is based on the appraisal of novelty, which leads to surprise that directly determines the formation of flashbulb memories. The second path involves an emotional feeling state, which is jointly determined by importance/consequentiality, surprise, and affective attitude. The emotional feeling state then indirectly influences the formation of flashbulb memories through overt rehearsal and memory of the original event. As Finkenauer et al. pointed out, all three models generally agree on a set of variables that are important. However, the emotional-integrative model specifies exactly how these variables work together to form flashbulb memories.

Based on the review of the literature, we determined that the nuclear accident in Tokaimura included all the variables that are necessary for the formation of flashbulb memories. That is, the accident was novel, surprising, and, most of all, personally consequential because the accident was life-threatening to the residents of Tokaimura and the surrounding area. Only one study has dealt with a situation that was life-threatening to the individuals who formed flashbulb memories. Neisser, Winograd, Bergman, Schreiber, Palmer, and Weldon (1996) compared memories of those who experienced the California earthquake in 1989 (students at universities in Berkeley and Santa Cruz, California) and those who heard the news about the earthquake (students at a university in Atlanta, Georgia). As expected, those who experienced the earthquake showed greater accuracy in their memories than those who did not. However, as these researchers stated, most of their ''subjects were not seriously concerned for themselves because, in fact, their local situations were not dangerous'' (p. 348). Further, for Californians, experiencing the earthquake was not surprising or emotional. Thus, the earthquake in California was not novel, surprising, and personally consequential. Accordingly, we determined that the event in Tokaimura, which included all three components, was an ideal event to investigate the formation of flashbulb memories.

Further, we were interested in whether people in Japan would form flashbulb memories similar to people in Western countries. As far as we know, studies on flashbulb memories have never been conducted in Japan. It is possible that people in Asia do not form memories of life-threatening situations in the same way that people in Western countries do. In fact, Cohen and Gunz (2002) suggest a possible difference in how Easterners and Westerners remember past events. In addition, we wanted to know whether flashbulb memories can be predicted *a priori*. Flashbulb memories should occur when the target event is highly emotional (e.g., Bohannon, 1988; Schmidt & Bohannon, 1988). We therefore predicted that this, presumably, intensely emotional event should have produced widespread flashbulb memories among those who lived near the accident site. Another purpose of the present study was to investigate whether age would influence the formation of flashbulb memories. Cohen et al. (1994) showed that the occurrence of flashbulb memories was much lower among older adults (64 years old and older) than young adults (90% versus 42%). However, their target event, the resignation of British prime minister, was not life-threatening, even though it was nationally consequential (i.e., the end of an era in British history). Accordingly, it is possible that the occurrence of flashbulb memories would be similar between young and older adults when their lives are being threatened (i.e., when the target event is biologically significant).

We accomplished these goals by distributing a questionnaire approximately 3 weeks after the accident to (1) the residents of the communities surrounding the accident site (hereafter referred to as Ibaraki residents), (2) the students at a university near the accident site (Tokiwa University; hereafter referred to as Ibaraki university students), and (3) the students at two universities far away from the accident site (Kyoto University and Konan Women's University; hereafter referred to as Kansai university students). We then repeated the questionnaire 1 year later.

METHOD

Participants

A total of 139 participants filled out two questionnaires. Because one participant failed to provide age, we conducted analyses based on 138 participants from three groups: Ibaraki residents, Ibaraki university students, and Kansai university students. Ibaraki residents consisted of 26 men and 34 women, ranging in age between 20 and 77 years old (M = 47.08, SD = 14.00). They lived between 1 km and 20 km (M = 10.13, SD = 4.31) from the accident site. Ibaraki university students consisted of 8 men and 27 women between 19 and 28 years old (M = 20.63, SD = 1.59) who lived between 7 km and 50 km (M = 18.14, SD = 8.60) from the accident site. Kansai university students were 8 men and 35 women, ranging in age between 19 and 37 years old (M = 22.88, SD = 3.93). Kansai students were used as the comparison group because they lived much farther from the accident site (between 400 km and 550 km, M = 451.51, SD = 18.54) than Ibaraki residents and Ibaraki university students. Because we were interested in age differences, we divided the participants from Ibaraki prefecture (Ibaraki residents and Ibaraki university students) into three age groups: young, middle-age, and older. The young group ranged in age between 19 and 28 (M = 21.30, SD = 2.47, n = 43); the middle-age group ranged in age between 31 and 48 (M = 40.00, SD = 5.81, n = 21); and the older group ranged in age between 50 and 77 (M = 57.77, SD = 8.22, n = 31).

Questionnaire

The questionnaire consisted of 11 cued recall items, 1 free recall item, and 12 rating scales. These items were developed based on several previous studies (Bohannon, 1988; Conway et al., 1994; Weaver, 1993). Table 1 summarises the content of these items; the questions listed in the table are the translations of the questions in the questionnaire. As shown, the cued recall items were used to probe memories surrounding the discovery of the accident. A 9-point confidence rating scale (1 = not confident at all; 9 = very confident) was also provided for each of these items. The free recall item was used to assess any significant memories they had about that day. This item was not accompanied by a confidence rating scale. The 12 rating scales were used to probe various attributes of the accident. These scales were 9-point scales except for items 14 and 15 that probed the extent of rehearsal and media exposure with a 6-point scale (1 = not at all; 6 = over 30 times).

The first questionnaire was distributed to Ibaraki residents in the middle of October 1999 (approximately 3 weeks after the accident) by the father of the first author and his friends and relatives who lived near the accident site. We offered small gifts a few months later to those who helped distribute the questionnaires. Around the same time, the student volunteers at Ibaraki and Kansai universities received the first questionnaire from their instructors. The second questionnaire was sent by mail in October 2000 to all participants who indicated on the first questionnaire that they were willing to participate in the unspecified second phase of the project 1 year later. The second questionnaire was the same as the first questionnaire. In other words, we did not ask participants to recollect their reactions (e.g., surprise) that they had 1 year ago. Rather, we probed their current reactions because flashbulb and non-flashbulb memory holders might be distinguished by their reactions a year later. Our assumption was that it would be normal to be upset over the accident immediately after it had occurred. However, those who maintained their flashbulb memories might be those who maintained their reactions over the 1-year period. The return rate of the second questionnaire was 67% (n = 139). A small gift was offered to each of these participants.

RESULTS

Memory scores

The responses on cued and free recall items were scored according to the scoring scheme used by Conway et al. (1994) and Cohen et al. (1994). These researchers assigned the score of 2 for those responses that were the same between test and retest, 1 for those responses that were similar but were not the same, and 0 for those responses that were different. The score of 0 was also given for no response. Using this scoring scheme, two raters scored the responses provided by Ibaraki residents (n = 60). Because the correlations between these two raters were high (Pearson correlations ranged from r = .70 to 1.00, M = 0.83, SD = 0.15), one rater scored the rest of the participants (n = 78).

TABLE 1
Items used in the questionnaire

Cued recall items	
Item 1	From where did you receive the news? (source)
Item 2	From whom did you get the news? (person)
Item 3	Who was the last person you talked to before hearing the news? (last person)
Item 4	What day of the week did the accident occur? (day)
Item 5	What was the weather on that day? (weather)
Item 6	What time did you receive the news? (time)
Item 7	Where were you when you received the news? (place)
Item 8	What were you doing when you received the news? (activity)
Item 9	With whom were you with when you received the news? (people)
Item 10	What were you wearing when you received the news? (clothes)
Item 11	What were you thinking when you received the news? (thoughts)
Free recall item	
Item 13	Please write down what you remember from that day (free recall)
Rating scales	
Item 12	How much did the news disrupt your on-going activities? (disruption)
Item 14	How many times did you talk about it with other people? (rehearsal)
Item 15	How many times did you receive exposures from the media? (media exposure)
Item 16	How upsetting was it? (upset)
Item 17	How distinct was it? (distinctiveness)
Item 18	How personally consequential was it? (personal consequentiality)
Item 19	How consequential was it to the nation? (national consequentiality)
Item 20	How memorable was it? (memorability)
Item 21	How surprising was it? (surprise)
Item 22	How meaningful was it? (meaningfulness)
Item 23	How frequently have you encountered this event in the past? (frequency)
Item 24	Rate each emotional reaction: sadness, anger, disgust, and fear

Labels used throughout this paper are in parentheses.

To determine the number of participants who formed flashbulb memories, we computed flashbulb memory scores (FBM scores) by combining the scores from items 1 (source) through 13 (free recall) except items 2 (person) and 12 (disruption). Item 2 (person) was excluded because most participants did not write the name of the person who provided the news because they had received the news from the media. Item 12 (disruption) was a rating scale that probed the amount of disruption the news created in ongoing activities. Following Conway et al. (1994) and Cohen et al. (1994), flashbulb memory holders were defined as those who achieved 90% or higher FBM scores. Using this definition, very few participants qualified as flashbulb memory holders (n = 3; 2%). However, Conway et al. and Cohen et al. classified flashbulb and non-flashbulb memory holders based only on five memory attributes (source, place, activity, people, and description). We therefore computed a second set of FBM scores based on the items that reflected these five attributes: items 1 (source), 7 (place), 8 (activity), 9 (people), and 13 (free recall). This new FBM score increased the number of flashbulb memory holders (n = 20; 14%). However, the percentage of participants who formed flashbulb memories was still far smaller than that observed by Conway et al. (86%) and Cohen et al. (90% among young adults and 42% among older adults). Further, contrary to Cohen et al.'s results, the percentage of participants who formed flashbulb memories was similar for the young and older groups (young = 21% and older = 19%). The percentage was lower among the middle-age group (14%) and, as expected, much lower among Kansai university students (5%). We also examined the percentage of participants who developed flashbulb memories across each decade, because the older group in this study included participants who were younger than those older participants in Cohen et al.'s study. Although the small number of participants among 60- and 70-year-olds makes it difficult to compare across the age groups, the percentage of flashbulb memory holders did not decline as a function of age (Figure 1). In summary, these results indicated that despite the life-threatening nature of the event, only a small

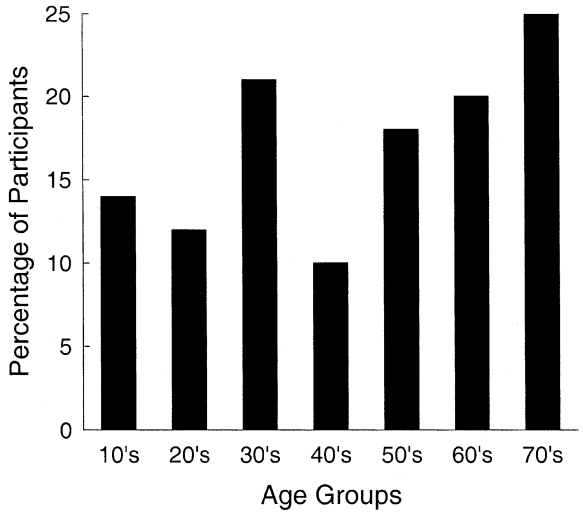

Figure 1. Percentage of flashbulb memory holders across each decade of age.

percentage of participants formed flashbulb memories. Further, we did not observe an age-related decline in the formation of flashbulb memories, even though this conclusion should be regarded as tentative due to a small number of older participants.

Next, we compared the memory scores of the flashbulb and non-flashbulb memory holders, to show that our definition of flashbulb memories successfully differentiated memory performance of the two groups. As shown in Figure 2, the mean memory scores were higher for the flashbulb memory holders than for the non-flashbulb memory holders on all items except item 4 (day). Not surprisingly, the flashbulb memory holders showed perfect or near perfect accuracy on four of the five attributes used to define flashbulb memories: items 1 (source), 7 (place), 8 (activity), and 9 (people). However, the accuracy on item 13 was much lower due to the open-ended nature of the question. We conducted a 4 (group: young, middle-age, older, and Kansai university students) $\times$ 2 (memory type: flashbulb and non-flashbulb) multivariate analysis of variance (MANOVA) using the above memory items as dependent variables. The results showed that only the effect of memory type was significant, Wilks' Lambda = 0.61, $F(11, 120) = 7.03$, $p < .00$, indicating that our definition of flashbulb memories successfully differentiated the flashbulb and non-flashbulb memory holders. To investigate which items showed the difference between the two, we

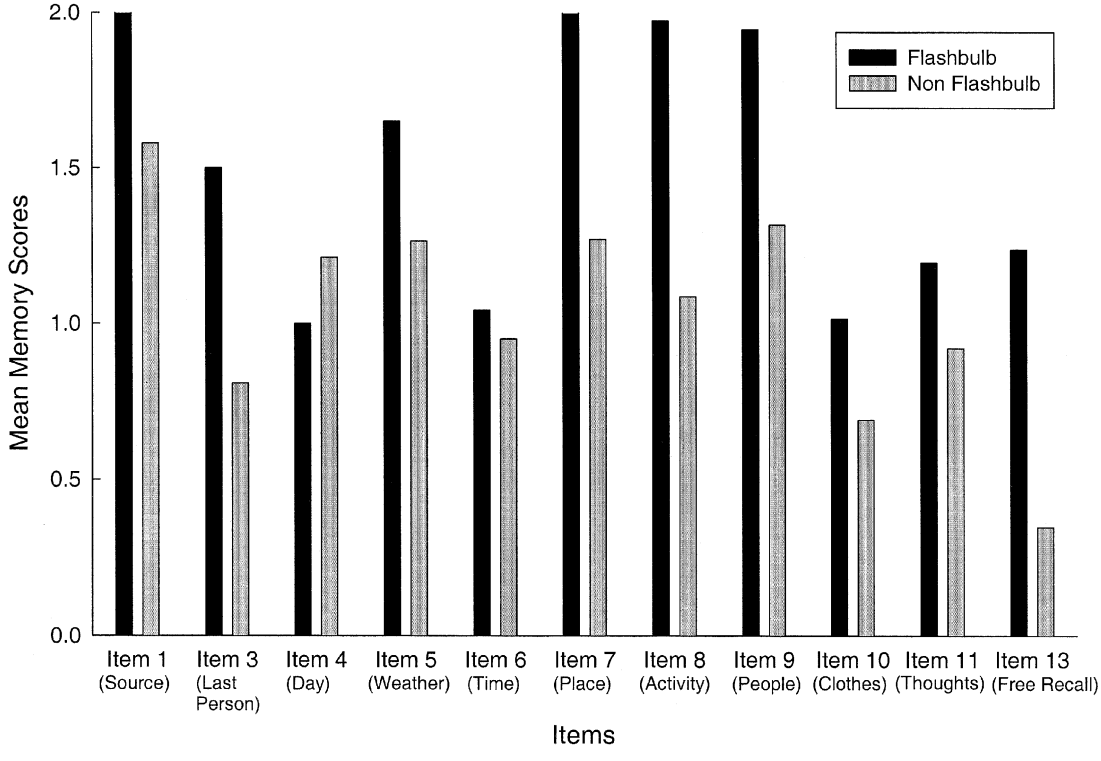

Figure 2. Mean memory scores between the flashbulb and non-flashbulb memory holders on all memory items except item 2.

examined the results of univariate analyses of variance (ANOVAs). These results revealed that the difference was significant on items 1 (source), 3 (last person), 7 (place), 8 (activity), 9 (people), and 13 (free recall) (Fs ranged from 4.85, $p < .03$, to 40.10, $p < .00$) whereas the difference was not significant on items 4 (day), 5 (weather), 6 (time), 10 (clothes), and 11 (thoughts). These results are consistent with the notion that flashbulb memories do not preserve all of the environmental details (Conway, 1995).

Confidence ratings on memory items

Figure 3 shows the mean confidence ratings as a function of memory type for the memory items except items 2 (person) and 13 (free recall). As mentioned earlier, few participants provided responses on item 2 (person) whereas a confidence rating scale was not provided for item 13 (free recall). The figure indicates that the mean ratings were higher for the flashbulb memory holders than for the non-flashbulb memory holders for all items. We conducted a 4 (group: young, middle-age, older, and Kansai university students) $\times$ 2 (memory type: flashbulb and non-flashbulb) $\times$ 2 (year: 1999 and 2000) MANOVA using all memory items except items 2 (person) and 13 (free recall) as dependent variables.[1] As expected, the effects of group, Wilks' Lambda = 0.32, $F(30, 276.59) = 4.39$, $p < .00$, and year, Wilks' Lambda = 0.63, $F(10, 94) = 5.62$, $p < .00$, were significant. However, the effect of memory type was not significant, Wilks' Lambda = 0.95, $F(10, 94) < 1$. As shown in Table 2, some of the group differences were based on the differences between the participants in Ibaraki prefecture (Ibaraki residents and Ibaraki university students) and Kansai university students, whereas the other differences were based on age. Further, confidence declined from 1999 to 2000. Because the flashbulb memory

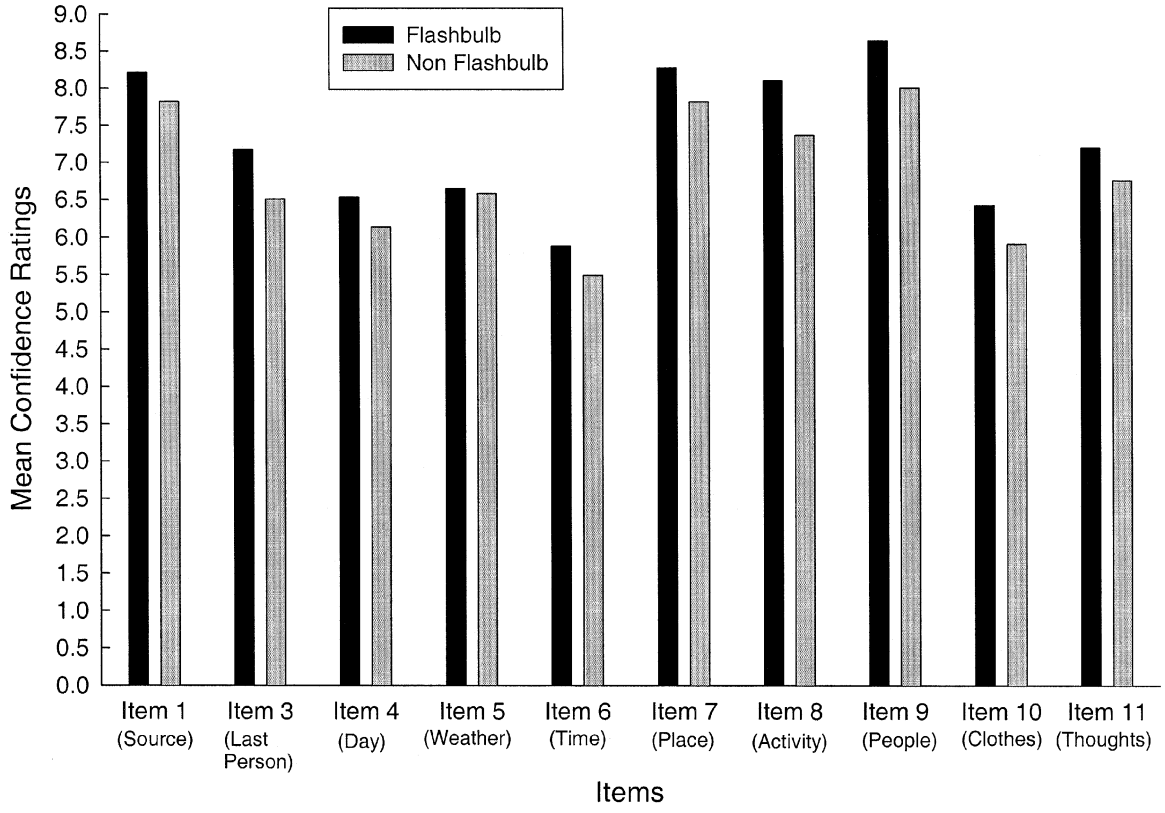

Figure 3. Mean confidence ratings between the flashbulb and non-flashbulb memory holders on all memory items except item 2.

[1] Due to missing values, we had to exclude 5 flashbulb memory holders and 22 non-flashbulb memory holders from this analysis.

TABLE 2
Mean confidence ratings as a function of group and memory item

	Group							
	Young		*Middle-age*		*Older*		*Kansai university students*	
Item	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Item 1 (source)	8.39	0.25	7.92	0.34	8.13	0.29	7.62	0.27
Item 3 (last person)	7.06[a]	0.40	7.26[a]	0.55	7.68[a]	0.47	5.37[b]	0.44
Item 4 (day)	6.66[a]	0.45	7.42[a]	0.61	7.75[a]	0.52	3.51[b]	0.49
Item 5 (weather)	7.12[a]	0.35	7.55[a]	0.47	7.38[a]	0.40	4.39[b]	0.37
Item 6 (time)	5.08[ab]	0.34	6.36[b]	0.47	7.08[c]	0.40	4.22[a]	0.37
Item 7 (place)	8.03[a]	0.28	8.35[a]	0.38	8.53[a]	0.33	7.25[b]	0.30
Item 8 (activity)	7.65[a]	0.30	8.25[ab]	0.42	8.34[ab]	0.36	6.68[ac]	0.33
Item 9 (people)	8.53	0.26	8.19	0.35	8.52	0.30	8.05	0.28
Item 10 (clothes)	4.92[a]	0.42	7.32[b]	0.58	7.89[b]	0.49	4.53[a]	0.46
Item 11 (thoughts)	6.86[a]	0.34	6.67[a]	0.47	8.32[b]	0.40	6.04[a]	0.37

For each item, different superscripts indicate significant differences based on Bonferroni tests.

holders showed higher memory accuracy on items 1 (source), 3 (last person), 7 (place), 8 (activity), and 9 (people), we conducted *a priori* analysis on each of these items to compare the confidence ratings between the flashbulb and non-flashbulb memory holders. Our hypothesis was that the flashbulb memory holders would show higher confidence than the non-flashbulb memory holders on all these items. The results of 2 (memory type: flashbulb and non-flashbulb) × 2 (year: 1999 and 2000) ANOVAs indicated that the effect of memory type was significant for item 8 (activity), $F(1, 133) = 6.25$, $MSE = 5.68$, $p < .01$, and item 9 (people), $F(1, 133) = 5.97$, $MSE = 4.15$, $p < .02$. The effect of memory type was only marginally significant for item 1 (source), $F(1, 136) = 3.52$, $MSE = 3.82$, $p < .06$, item 3 (last person), $F(1, 119) = 3.15$, $MSE = 10.16$, $p < .08$, and item 7 (place), $F(1, 134) = 3.32$, $MSE = 4.82$, $p < .07$. On all these items, the mean ratings were higher for the flashbulb memory holders than for the non-flashbulb memory holders. Further, the effect of year was significant for all these items except for item 1 (source) (*F*s ranged from 10.64, $p < .00$, to 15.21, $p < .00$), indicating that confidence ratings declined from 1999 to 2000. However, memory type did not interact with year on any items. These results, therefore, showed that the difference in confidence ratings between the flashbulb and non-flashbulb memory holders was not as large as the difference in memory accuracy between the two groups.

Rating scales

We conducted a 4 (group: young, middle-age, older, and Kansai university students) × 2 (memory type: flashbulb and non-flashbulb) × 2 (year: 1999 and 2000) MANOVA on rating scales (items 12 to 23 except for item 13, which was a memory item).[2] The results revealed that the effects of group, Wilks' Lambda = 0.28, $F(33, 342.46) = 5.59$, $p < .00$, and the group × year interaction, Wilks' Lambda = 0.64, $F(33, 342.46) = 1.70$, $p < .01$, were significant. However, the effect of memory type was not significant, Wilks' Lambda = 0.92, $F(11, 116) < 1$. The differences among the groups are shown in Table 3. As shown, the differences were mostly based on the differences between the participants in Ibaraki prefecture and Kansai university students. Further, the ratings declined from 1999 to 2000 for most items; however, for some items—15 (media exposure), 18 (personal consequentiality), and 19 (national consequentiality)—the amount of decline was different among the groups. Because personal consequentiality, surprise, and rehearsal are considered to be crucial components of flashbulb memory (e.g., Brown & Kulik, 1977), we conducted *a priori* comparisons between the flashbulb and non-flashbulb memory holders on

[2] Due to missing values, we had to exclude two flashbulb memory holders and five non-flashbulb memory holders.

TABLE 3
Mean ratings as a function of group and rating item

	Group							
	Young		*Middle-age*		*Older*		*Kansai university students*	
Item	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Item 12 (disruption)	4.48	0.41	3.66	0.57	3.69	0.50	3.48	0.46
Item 14 (rehearsal)	4.81[a]	0.16	5.11[a]	0.22	4.75[a]	0.19	3.00[b]	0.17
Item 15 (media exposure)	5.26[a]	0.13	5.66[a]	0.18	5.48[a]	0.16	4.48[b]	0.15
Item 16 (upset)	6.36	0.34	5.75	0.47	6.76	0.41	6.17	0.38
Item 17 (distinctiveness)	7.83[a]	0.28	7.92[a]	0.39	8.33[a]	0.34	6.90[b]	0.31
Item 18 (personal consequentiality)	5.38[a]	0.33	5.91[ab]	0.46	6.38[b]	0.40	4.64[a]	0.37
Item 19 (national consequentiality)	7.94	0.19	7.99	0.26	8.28	0.22	8.07	0.21
Item 20 (memorability)	7.17[a]	0.29	7.12[a]	0.40	8.31[b]	0.34	5.96[c]	0.32
Item 21 (surprise)	6.92	0.32	6.27	0.44	7.12	0.38	6.92	0.35
Item 22 (meaningfulness)	7.69[a]	0.24	7.76[a]	0.33	8.05[a]	0.29	7.00[b]	0.26
Item 23 (frequency)	2.04[a]	0.27	2.52[a]	0.37	2.61[a]	0.32	3.68[b]	0.30
Item 24 (sadness)	3.88[a]	0.40	3.88[a]	0.55	5.70[b]	0.48	4.37[a]	0.44
Item 24 (anger)	5.73[a]	0.36	6.20[a]	0.49	7.56[b]	0.42	5.83[a]	0.39
Item 24 (disgust)	5.98	0.38	6.15	0.52	6.92	0.45	6.19	0.42
Item 24 (fear)	7.45	0.30	7.30	0.41	7.85	0.36	7.19	0.33

For each item, different superscripts indicate significant differences based on Bonferroni tests.

the items that probed these components: items 14 (rehearsal), 18 (personal consequentiality), and 21 (surprise). The results of 2 (memory type: flashbulb and non-flashbulb) × 2 (year: 1999 and 2000) mixed-design ANOVAs showed that for item 14 (rehearsal), only the effect of memory type was significant, $F(1, 135) = 4.47$, $MSE = 3.11$, $p < .04$. As expected, the mean rating was higher for the flashbulb memory holders ($M = 4.80$, $SE = 0.28$) than for the non-flashbulb memory holders ($M = 4.16$, $SE = 0.12$). In contrast, none of the effects was significant for items 18 (personal consequentiality) and 21 (surprise). That is, no difference was found between the flashbulb and non-flashbulb memory holders on personal consequentiality ($M = 5.47$, $SE = 0.46$ versus $M = 5.64$, $SE = 0.19$) and surprise ($M = 7.21$, $SE = 0.42$ versus $M = 6.69$, $SE = 0.17$). These results, therefore, indicated that rehearsal was the only component that differentiated the flashbulb memory holders from the non-flashbulb memory holders.

Emotional ratings

We also conducted a 4 (group: young, middle-age, older, and Kansai university students) × 2 (memory type: flashbulb and non-flashbulb) × 2 (year: 1999 and 2000) MANOVA on emotionality ratings on item 24 (sadness, anger, disgust, and fear).[3] The results showed that only the effect of group was significant, Wilks' Lambda = 0.83, $F(12, 331.01) = 2.04$, $p < .02$. In other words, the effect of memory type was not significant, Wilks' Lambda = 0.95, $F(4, 125) = 1.54$. As shown in Table 3, the effect of group was based on the older group having higher ratings than the other groups on sadness and anger. Because emotional reaction was assumed to be the key component of flashbulb memory, we conducted *a priori* analyses comparing the flashbulb and non-flashbulb memory holders on these emotionality ratings. Our hypothesis was that the flashbulb memory holders would show higher emotional ratings than the non-flashbulb memory holders on all four rating scales. However, 2 (memory type: flashbulb and non-flashbulb) × 2 (year: 1999 and 2000) mixed-design ANOVAs showed that none of the effects were significant (see Figure 4). Thus, emotional reactions did not differentiate the flashbulb and non-flashbulb memory holders.

[3] Due to missing values, we had to exclude one flashbulb memory holder and four non-flashbulb memory holders.

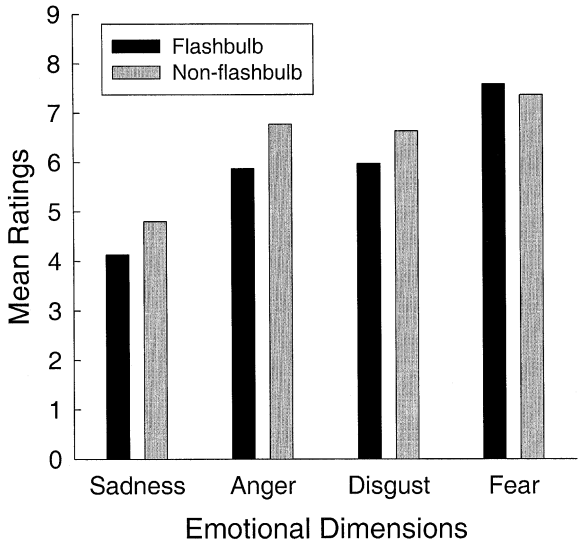

Figure 4. Mean ratings between the flashbulb and non-flashbulb memory holders on four emotional dimensions; sadness, anger, disgust, and fear.

DISCUSSION

The goal of the present study was to examine whether people who lived near the accident site formed flashbulb memories. As mentioned earlier, we determined that the nuclear accident in Tokaimura included all the variables that are necessary to produce flashbulb memories. That is, the accident was novel, surprising, and personally consequential. Further, the accident should have been emotionally arousing because people's lives were threatened by harmful radiation. Accordingly, we predicted *a priori* that this event would trigger flashbulb memories, even among older adults. However, contrary to our expectation, the percentage of participants who formed flashbulb memories was surprisingly small. Based on the definition used by Conway et al. (1994) and Cohen et al. (1994), only 14% of our participants were classified as flashbulb memory holders. The percentage was even smaller (3%) when all the memory items were used to define flashbulb memory holders. These results are similar to the results obtained by Neisser and Harsch (1992), who reported that only 7% of their participants showed consistent memories between test and retest. In contrast, Conway et al. and Cohen et al. showed a considerably higher percentage of participants forming flashbulb memories (over 85% among young adults) for an event that was not life-threatening to their participants (i.e., the resignation of the prime minister). These results therefore indicate that it is difficult to predict *a priori* which event would trigger widespread flashbulb memories.

Did our participants actually develop flashbulb memories? Given that only a small number of our participants were classified as flashbulb memory holders, it is possible that these participants did not form flashbulb memories, and instead what they developed were simply vivid autobiographical memories. This would explain the results that none of the variables that were shown to influence the formation of flashbulb memories, other than rehearsal, differentiated the flashbulb and non-flashbulb memory holders. However, our objection to this argument is that it is difficult, if not impossible, to distinguish between flashbulb and vivid autobiographical memories. If one argues that flashbulb memories, by definition, are associated with high levels of emotions, then it would be impossible to show that flashbulb memories are not associated with high levels of emotions. Further, based on this definition, how could one distinguish flashbulb memories and vivid autobiographical memories that are emotional in nature? Perhaps it requires the identification of the brain parts that are activated while retrieving these memories. For instance, Conway et al. (1999) used positron emission tomography and found that the retrieval of autobiographical memories was distinguished by the activation of the left frontal lobe whereas recall of paired associate items was not. It might be possible that using the same technique, autobiographical memories could be further differentiated into flashbulb memories and ordinary autobiographical memories. However, until then, our assumption is that our participants, albeit a small number, developed flashbulb memories.

Why did so few participants form flashbulb memories? It is possible that the difference in population was responsible. Perhaps Japanese people are less emotional than people in Western countries and, as a consequence, are less likely to form flashbulb memories. In fact, the percentages of Ibaraki residents and Ibaraki university students who rated 9 out of 9 in 1999 on sadness (17%), anger (43%), disgust (43%), and fear (54%) were low considering the seriousness of the accident. These percentages were similar to the percentages of students at Central Michigan University who rated 9 out of 9 on sadness (44%), anger (40%), disgust (53%), and fear (23%) after the terrorist attacks on 11 September 2001, even

though the attacks were not life-threatening to these students. However, the percentage of flashbulb memory holders (14% overall and 19% among Ibaraki residents and Ibaraki university students) was much smaller than the percentages of participants who rated 9 out 9 on each emotional dimension. Therefore, the low emotional reactions shown by Japanese people alone would not account for the low occurrence of flashbulb memories. It is also possible that Japanese people remember personal episodes differently from Westerners and, as a consequence, are less likely to develop flashbulb memories. A possible difference between Easterners and Westerners in remembering past events was reported by Cohen and Gunz (2002). These researchers showed that Easterners, relative to Westerners, have a greater tendency to remember past events from the third-person perspective, especially when they themselves are at the centre of the attention. That is, Easterners have a higher tendency to describe what they experienced in the past as if they are observing themselves from outside. Such a difference may account for the low occurrence of flashbulb memories among our participants, because flashbulb memories place participants themselves at the centre of attention. Perhaps, the focus of attention may be different when one remembers past events from the third-person perspective. Consequently, Japanese people may not remember the canonical features that are typical of flashbulb memories of Westerners.

Further, how participants were informed of the accident may also account for the low incidence of flashbulb memories. Although the event was life-threatening, and 54% of Ibaraki residents and Ibaraki university students rated 9 out of 9 on fear, the seriousness of the situation did not become clear all at once. Thus, when participants received the news initially, the news may not have conveyed the seriousness of the accident. In support of this notion, most of the responses on the free recall items were not very dramatic. For example, one participant wrote that police at a road block told her to go home and stay inside because there was an accident at the nuclear power plant. Also, unlike the events investigated by the other researchers, the situation was rather vague. The accident did not offer a dramatic visual scene, such as an explosion like the space shuttle *Challenger* disaster. Also, unlike Mrs Thatcher's resignation, many people had only a vague understanding of what radiation contamination meant. For example, one participant wrote that she was concerned about getting to the airport on time instead of worrying about how radiation would have affected her health. Thus, even though the situation was considered to be serious after the details of the accident were finally disclosed, it might be the case that people were not frightened enough by the initial news of the accident. In fact, the second author described the seriousness of the accident as seeping out over time like toxic radiation.

It is also possible that the questionnaire did not adequately probe participants' memories. Flashbulb memories may be unique to individuals, so that the canonical features probed by the questionnaire may not have adequately revealed what participants remembered. However, it is the regularity of the features that appear in flashbulb memories that have impressed previous researchers (e.g., Brown & Kulik, 1977). Further, we did provide a free recall item asking participants to describe any significant memories they had on that day. This item should have reflected the unique memories each individual had possibly developed. However, only 6% of our participants showed complete consistency between the two questionnaires on this item.

The initial questionnaire was distributed 3 weeks after the accident. It is possible that the initial memories had faded by the time participants filled out the questionnaire. This would also explain the low occurrence of flashbulb memories, because if the initial memories were not sufficiently strong, the likelihood of maintaining the memories over 1-year period would be very low. However, if we define flashbulb memories as long-lasting memories of details associated with emotional events, these memories should have persisted over the initial 3-week period. Thus, it is difficult to conceive that the delay in distributing the first questionnaire is solely responsible for the low occurrence of flashbulb memories in this study, unless recalling on the first questionnaire actually creates flashbulb memories by increasing their strength. Further, Neisser and Harsch (1992) showed a low occurrence of flashbulb memories (7%) even though they distributed their initial questionnaire less than a day after the space shuttle *Challenger* disaster. Therefore, distributing the initial questionnaire immediately after the event does not guarantee a high occurrence of flashbulb memories.

In summary, we conclude that flashbulb memories were observed in this study, even though the number was small. Further, contrary to Cohen et al., the percentage of flashbulb memory holders

was similar between the young and old groups. This result was further corroborated by the observation that the percentage of flashbulb memory holders did not decline across age groups when participants were grouped based on each decade. Obviously, the small number of participants, especially among the 60- and 70-year-old groups, makes the comparison tentative. However, our results are consistent with Davidson and Glisky (2002) who reported no age differences in memories of the deaths of Princes Diana and Mother Teresa. Unfortunately, these researchers did not separate flashbulb and non-flashbulb memory holders. Thus, further studies are needed to investigate age differences in flashbulb memories.

What were the characteristics of flashbulb memories? Consistent with Conway et al. (1994), the flashbulb memory holders showed perfect or near perfect consistency between test and retest for source, place, activity, and people. However, contrary to Conway et al., the flashbulb memory holders did not show perfect or near perfect scores on description, even though the mean on this item (item 13) was higher for the flashbulb memory holders than for the non-flashbulb memory holders. It is likely that the way the question was asked accounts for the low mean score on this item. Conway et al. specifically asked participants to describe the reception events (i.e., the events surrounding the reception of the news) whereas we asked participants to describe any significant memories they had on that day. In other words, we did not directly probe the reception events. Thus, if we had asked participants to describe how they received the news, their scores may have been much higher. In contrast to these items, the scores were similar between the flashbulb and non-flashbulb memory holders on day, time, clothes, and thoughts. These results are consistent with one of McCloskey et al.'s (1988) criticisms of the strong form of the flashbulb memory hypothesis. That is, contrary to the notion of the ''now print'' mechanism, flashbulb memories do not preserve the complete records of events surrounding the reception of surprising and consequential news. However, Conway (1995) asserted that Brown and Kulik (1977) never claimed that flashbulb memories preserve the complete records of the reception events and, instead, argued that flashbulb memories preserve reception events in an indiscriminate manner.

What were the other differences between the flashbulb and non-flashbulb memory holders? The analyses of confidence ratings indicated that the flashbulb memory holders showed somewhat greater confidence than the non-flashbulb memory holders on those memory attributes (source, place, people, and activity) where they showed perfect or near perfect scores. However, the difference was small, indicating that confidence ratings did not reflect the large difference in memory scores that differentiated the flashbulb and non-flashbulb memory holders. Nevertheless, the correlation between the confidence ratings—averaged across all the memory items except items 2 (person) and 13 (free recall)—and the memory scores—averaged across all memory items except item 2 (person)—was positive and statistically significant ($r = .34$, $p < .00$ for all participants and $r = .31$, $p < .00$ for the Ibaraki participants) unlike a non-significant correlation ($r = .29$) reported by Neisser and Harsch (1992). Thus, the results of the present study did not show the dramatic dissociation between confidence and memory accuracy shown by Neisser and Harsch.

Surprisingly, emotional reactions did not distinguish between the flashbulb and non-flashbulb memory holders. As shown, the flashbulb memory holders were no more sad, angry, disgusted, or afraid than the non-flashbulb memory holders. These results are inconsistent with the flashbulb memory hypothesis proposed by Brown and Kulik (1977) and advocated by other researchers (e.g., Bohannon, 1988; Bohannon & Symons, 1992; Conway, 1995; Conway et al., 1994; Schmidt & Bohannon, 1988). However, our results are consistent with the results obtained by Neisser et al. (1996). These researchers reported that the ratings on emotional reaction scales (terrified, concerned, having strong emotion) did not correlate with the recall of the details associated with the California earthquake of 1989 and the collapse of the Bay Bridge during that earthquake. Thus, emotional reaction may not be an important determinant of flashbulb memories. Further, the present results showed that the degree of surprise and personal consequentiality did not differentiate the flashbulb and non-flashbulb memory holders. Brown and Kulik proposed surprise and consequentiality to be the two crucial components of flashbulb memories. It is entirely possible that the lack of differences were Type II errors. However, Pillemer (1984) and Christianson (1989) also reported that consequentiality was not related to memory consistency between test and retest, even though surprise was related.

It is also possible that the accident was not as surprising and personally consequential to our participants as we assumed. In fact, the percentage of Ibaraki residents and Ibaraki university students who rated 9 out of 9 on item 18 (personal consequentiality) was low (24%). However, the percentage of these participants who rated 9 out of 9 on item 21 (surprise) was much higher (45%), higher than the percentage of flashbulb memory holders (19% among Ibaraki residents and Ibaraki university students).

In contrast to these components, the present results showed that the degree of rehearsal was significantly greater for the flashbulb memory holders than for the non-flashbulb memory holders. The present results, therefore, are consistent with the notion advocated by Neisser (1982) and Neisser et al. (1996) that flashbulb memories are not established at encoding but, rather, established through rehearsal. However, it is also possible that flashbulb memory holders rehearsed more than non-flashbulb memory holders because they remembered the details associated with the target event. Thus, flashbulb memories may not be the result of rehearsal—rather, rehearsal is the result of flashbulb memories. This is especially plausible in our study because our question stated ''How many times have you talked about it (news) to other people?''. Perhaps those who had something to tell (flashbulb memory holders) were more likely to talk to other people than those who did not have anything to tell (non-flashbulb memory holders). Further, not all flashbulb memory holders rated 6 out of 6 on rehearsal (40% in 1999 and 45% in 2000 among the participants in Ibaraki prefecture). Unfortunately, whether rehearsal causes flashbulb memories or flashbulb memories cause rehearsal cannot be determined unless rehearsal is directly manipulated.

However, there is evidence from laboratory studies that rehearsal may not be responsible for better memories of emotionally arousing events relative to emotionally neutral events. In a laboratory experiment, Guy and Cahill (1999) asked participants to watch emotionally arousing and neutral film clips. Participants were then instructed to either overtly talk about the films (the overt narrative condition) or not to discuss the films with anyone (the no talk condition). The results showed that regardless of rehearsal, the emotionally arousing film was remembered better than the emotionally neutral film. Similarly, Libkuman, Stabler, and Otani (2004) prevented some participants from rehearsing by asking them to perform a distractor task between to-be-remembered slides. The results showed that emotionally arousing slides were remembered better than emotionally neutral slides even when rehearsal was prevented. These results therefore suggest that flashbulb memories may not be the results of rehearsal. However, in Libkuman et al.'s study, rehearsal did interact with valence (positive and negative) of the slides. That is, the negatively valenced slides (i.e., the slides with unpleasant scenes) were remembered better when participants did not perform the distractor task than when they performed the distractor task. Thus, given that flashbulb memories are mostly based on negatively valenced events (as far as we know, no one has studied flashbulb memories of positively valenced events), rehearsal may play an important role in creating flashbulb memories.

In conclusion, the nuclear accident in Tokai-mura did produce flashbulb memories, but only in a small number of participants. Further, contrary to the flashbulb memory hypothesis advocated by other researchers (e.g., Brown & Kulik, 1977), emotional reactions, personal consequentiality, and surprise did not differentiate between flashbulb and non-flashbulb memory holders. The only difference we found was that the flashbulb memory holders rated higher on rehearsal than the non-flashbulb memory holders. These results are supportive of Neisser and colleagues' (Neisser, 1982; Neisser et al., 1996) notion that flashbulb memories are created through rehearsal rather than at encoding. However, it is also possible that flashbulb memory holders rehearsed more than non-flashbulb memory holders because the former group remembered the details associated with the target event. Further studies are needed to investigate the role of rehearsal in the formation of flashbulb memories.

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