

Relationship Between Episodic Memory Formation and Two Minds

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Abstract This paper presents evidence that even if two individuals exhibit similar reactions caused by their autonomous nervous systems towards the same external stimuli, one may form a memory that can be recalled consciously, whereas the other may form a memory that cannot be processed consciously. We had fifteen monitors watch films, and we recorded their heart rates (HRs). Two monitors exhibited similar autonomous nervous system reactions, measured by HR, to the same films. We conducted interviews and compared their episodic memory about the films that both watched. One monitor was able to verbalize in detail her behavior, whereas the other could recall little of what he had watched. We suggest that this phenomenon can be explained by assuming that for the two monitors System 1 of Two Minds worked similarly to external stimuli, whereas System 2 worked differently for each monitor, affecting the formation of episodic memory in terms of conscious recall-ability.

Introduction

The retrospective interview is an efficient method for clarifying people's decision-making process. We developed a retrospective interview-based study methodology, called *Cognitive Chrono-Ethnography* (CCE) [1, 2]. We then conducted a series of studies on the behavior of tourists at hot spring resorts [1] and of spectators of professional baseball games [2] in an effort to find an effective methodology for understanding the relationship between an individual's experience and observed behavior at the moment, and chronological development. CCE is based on the assumption that human beings' decision-making should be considered the result of the workings of *Two Minds* [3, 4] and human beings' memory should be considered an autonomous system. This approach is modeled after the *Model Human Processor with Real-Time Constraints* (MHP/RT) developed by us [5].

The *retrospective-interview-based methodology* uses consciously recallable episodic memory to understand monitors' observed behavior. However, when one is experiencing an event, his or her Two Minds work in parallel and differ from person to person, the result may be the formation of individually different episodic memory for the same event. Therefore, apparent similarity in observed behaviors does not always guarantee that similar episodic memory has been formed. Formation of episodic memory should be considered a process other than experiencing external stimuli in real time to react immediately.

This paper describes the investigation of the relationship between monitors' experience and their episodic memory when watching short films for the first time in a movie theater. The movie theater provides the ideal environment for this study because all the information comes from a big screen and a set of loud speakers in a synchronized way so as to occupy the monitors' senses of sight and hearing completely: they are forced to concentrate on watching the films.

A CCE Study to Observe Monitors' Behavior at SSF

Study monitors participated in SSF (Sapporo Short Film Festival) in a manner that was typical of film viewers. Their activities were recorded during two 90-minute programs. Each monitor was required to attend two 90-minute retrospective interview sessions in the following month.

Recruiting Monitors. We conducted a Web survey. A total of 232 respondents provided valid answers and demonstrated a willingness to participate in the study. By analyzing their responses, we identified five groups with different attitudes towards viewing films. We finally chose 15 study monitors (6 males and 9 females, 21 to 56 years old).

Observation of Participants' Behavior at SSF. We had the monitors select two 90-minute programs. We recorded their viewing behavior in four ways: (1) by using a DVD camera recorder located at the back of the theater to capture their film-viewing behavior, (2) by recording their vocalizations with a pin microphone, (3) by installing a small ear-mounted CCD camera to record the scene they were viewing, and (4) by using an electrocardiograph and an accelerometer to capture their physiological responses to the events in the film.

Retrospective Interview. After SSF, we conducted two interview sessions with each study monitor. During the interviews, we used the record of the ear-mounted camera and the microphone to show the monitors how they behaved from the first person point of view, and of the image from behind to show the entire view of the scene in order to help them recall what they thought and did at the time their behavior was recorded. The first interview was conducted to describe the monitor's behavior during SSF and identify the reasons and mental state behind the observed behavior. The second interview was conducted to clarify the relationship between monitors' behavior and their preferences.

Results

Autonomic Nervous System Reaction. We measured the electrocardiogram (ECG) of the study monitors while they were watching short films. R-waves were detected from each ECG waveform. Time intervals between two successive R-

waves (RR-intervals) were then calculated and recorded using a portable device. Instantaneous heart rate (HR) [bpm] was obtained by dividing 60 by the RR-interval. The human psychological condition affects autonomic nervous activity. Therefore, HR increases with sympathetic nerve activation and decreases with parasympathetic nerve activation. The autonomic nervous activity is mainly affected by an individual's psychological state while watching films at a movie theater, since body movement is minimal. Moreover, since the strength of light and sound of environmental factors other than the films are stable and small in a movie theater, the main factor affecting the autonomic nervous activity is the content of the films.

Monitors Who Exhibited Similar Autonomic Nervous System Reactions. Some monitors exhibited similar autonomic nervous system reactions to the same program. M-6 watched two short film programs, "Film Makers B" (F-B) and "National & Local B" (N-B). Three of the fifteen monitors watched program F-B, and six watched program N-B. We calculated the 30-second averaged HR sequence from instantaneous HR data in order to reduce the effect of artifact data. Figure 1 depicts the waveforms of the 30-second averaged HR of M-6 (top) and M-5 (bottom) watching program F-B.

We compared the averaged HR response patterns of the monitors. Figure 2 presents the scatter plots of the 30-second averaged HR sequence of M-6 and that of M-5. The correlation coefficient between the two was 0.33 ($p < 0.0001$). This result indicates a significant correlation between autonomic nervous activity response patterns to the short film program F-B in M-6 and M-5. This result was replicated for program N-B. These results suggest M-6's autonomic nervous activity response pattern to short films was most similar to that of M-5.

Memory of Events. By examining how two study monitors remembered the short films they watched in program F-B, we found that they exhibited similar reactions while watching the programs, but they exhibited very different memory in their responses during the retrospective interviews. M-6 barely remembered the contents. He commented, "I remember nothing" about five of twelve short films. As for the rest, he only vaguely remembered that he had watched the films.

Summary. The result of experiencing external events is directly expressed by autonomic responses. Therefore, M-6 and M-5 looked to have the same experience when watching the short films. At the same time, the experience can be accompanied by another process, *memorization*, which forms episodic memory of the external events that are consciously recallable. At this point, they seemed to have processed the stimuli very differently: M-6 did not process the films in such a way that memory of the films was consciously recallable, whereas M-5 did.

MHP/RT and Event Memory

In this section, we use MHP/RT to explain the processes that M-5 and M-6 carried out while they were watching the short films.

As indicated in MHP/RT (Figure 3), two different paths lead to behavioral action and are related to our analysis.

Path 1. The first path goes through *Perceptual Information Processing* and *Autonomous Automatic Information Processing*, and directly leads to *Behavioral Action Processing*. System 1 of the Two Minds determines the behavioral outcome. However, System 2 is not idle. Rather, System 2 may be used to process things that are not related to the film-watching activity (e.g., daydreaming about things that might have been triggered by the film contents but were not strongly related to them).

Path 2. The second path involves the *Conscious Information Processing System*, whose input is from the *Perceptual Information Processing System* and whose output will be integrated into the result of the *Autonomous Automatic Information Processing System*.

As denoted by the dotted oval in MHP/RT, the result of the *Behavioral Action Processing System* is transferred to memory, whose contents reflect how the information has been processed to generate action. Path 1 does not incorporate a conscious process related to the film. Therefore, the memory originating from Path 1 is not associated with the film-watching activity. However, the memory

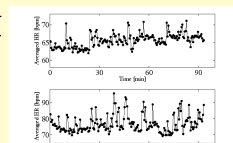


Figure 1. Thirty-second averaged HR waveform of M-6 (top) and M-5 (bottom) while watching program F-B with twelve short films.

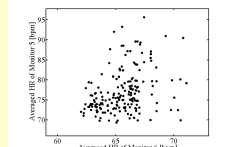


Figure 2. Scatter plots between the 30-second averaged HR sequence of M-6 and that of M-5 while watching program F-B. The correlation coefficient was $r = 0.33$ ($p < 0.0001$).

originating from Path 2 includes a memory construct that combines autonomic reactions to the film-watching activity and then-active entities that were consciously activated.

In summary, while watching the short films, M-5 formed episodic memory whose contents represents the result of the synchronized integration of Systems 1 and 2; therefore, in the retrospective interview, she could recall what System 2 did when she saw the behavior records, which were tied with memory related to System 1. This could happen because she watched the short films with some concrete purpose, and she felt strong impressions about the contents of the short films. M-6 did the opposite of what M-5 did, and did not form recallable episodic memory.

Conclusion

We hypothesized that the same experience would not result in formation of the same episodic memory because the experiencing of an event in real time and the formation of memory are different processes performed by Two Minds. Possible differences in the working of Two Minds and in the contents stored in long-term memory affect the formation of episodic memory of the event. We had our monitors watch short films and observed their behavior during the common experience in order to find evidence to support our hypothesis. We demonstrated that the film-watching behaviors of two monitors are consistent with the hypothesis. In addition, we provided an explanation of this phenomenon based on MHP/RT, which operationalizes Two Minds and is capable of simulating such human beings' behavior as watching films. Further studies will be needed to clarify the workings of Two Minds; MHP/RT will be useful for generating hy-

Model Human Processor with Real-Time Constraints

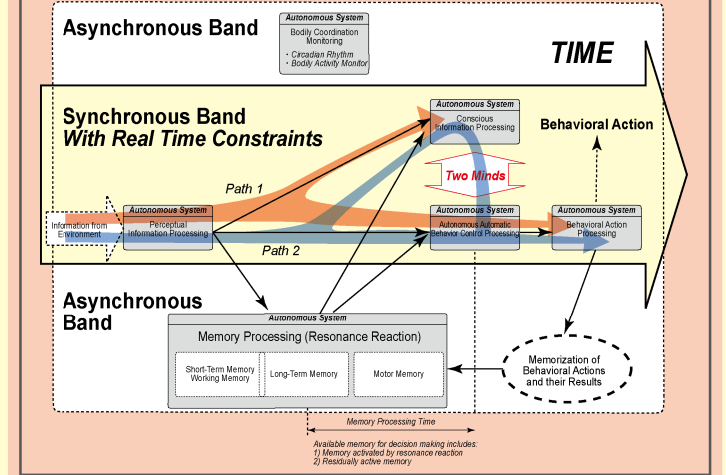


Figure 3. Schematic diagram of MHP/RT.

potheses and insights into how to design studies to test the hypotheses.

We designed an innovative study method that uses a physical environment consisting of a large projection screen, a set of loud speakers, and a dark closed space, to force the monitors' perceptual sensors to limit their input to the external stimuli and to concentrate on them. This setup is very different from that in a conventional psychology laboratory. We suggest this design for future research on Two Minds.

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