Physiological State Dependent Effects on Implicit Memory

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Abstract

The present study examined the existence of physiological state dependent effects (SDE) on implicit memory. A list of words was presented to participants while their physiological states were manipulated by exercise or rest. Participants then completed a conceptual implicit memory test called category production, while in a physiological state that matched or mismatched their physiological state at study phase. Results revealed that when participants exercised at study phase, the mean number of study list words generated by the participants with matched physiological states (exercised) at test phase was significantly higher than those with mismatched physiological states (rest) at test phase. However, when participants rested at study phase, the mean number of study list words generated by participants with matched physiological states (rest) at test phase was not significantly different from those with mismatched physiological states (exercised) during test phase. Our results lend partial support to the hypothesis that physiological SDE exists in implicit memory, provided that participants were physiologically aroused and tested with a conceptual implicit memory task.

Physiological State Dependent Effects on Implicit Memory

An increasing large body of research has been directed towards understanding state dependent effects (SDE) on memory since Godden and Baddeley's (1975) classic study. The study found that words studied on land were recalled better on land compared to recall under water, whereas words studied under water were recalled better under water compared to recall on land. Most studies have tested SDE on explicit memory, in which recollection of information needs reference back to a previous learning episode consciously (Medin, Ross & Markman, 2001). The relationship between SDE and implicit memory, which is the influence of prior experience on current thought or behavior without conscious recollection of the experience (Medin, Ross & Markman, 2001), has yet to be fully explored. The few studies that have investigated SDE on implicit memory are inconsistent, with some finding SDE on implicit memory (Schab, 1990; Smith, Heath & Vela, 1990), while others do not (Jacoby, 1983; McKone & French, 2001). Further research is necessary to address this inconsistency in the SDE literature.

Among the studies, which investigated SDE on explicit and implicit memory, most studies have focused on environmental (external) variables. The participants took the explicit or implicit memory test in an environment which was physically the same or different from the study environment. The performance of participants with same study-test environment was then compared to the performance of participants with different study-test environment (Godden & Baddeley, 1975; Jacoby, 1983; McKone & French, 2001). Research suggests that explicit memory can be affected by external cues such as environmental variations like setting or temperature (see Smith, 1988, for a review). Several studies also suggested that internal variables such as mood had an effect on explicit memory (Bower, 1981; Lang, Craske, Brown & Ghaneian, 2001). For example, Lang, Craske, Brown and Ghaneian (2001) demonstrated that participants recalled more words when they studied and completed the test in the same emotional state, rather than in different study-test emotional states. Despite the research of SDE of internal variables on explicit memory, internal variables have been relatively neglected in the investigation of SDE on implicit memory. One of the few studies that explored the influence of internal states on implicit memory has shown that participants were more easily primed with words whose meaning was congruent with the participants' mood (Tosun & Dag, 2000). With evidence given by research on explicit and implicit memory, it is reasonable to suggest that mood might have an influence on memory. However, it is almost impossible to completely manipulate moods within individuals (Ryan & Eich, 2000). One of the main reasons is that most of the manipulation checks of participants' moods are based on self-reports. Thus, the success of the internal states manipulation may not be objective.

In those studies of SDE on memory in which participants' mood was manipulated, physiological changes may have occurred in concert with psychological changes. For example, past research has shown that participants' highly hostile mood after playing a violent video game was highly correlated with an increase in heart rate (Panee & Ballard, 2002). It is then reasonable to conclude that physiological factors may also be contributing to the results of psychological SDE on memory. It remains to be seen, however, which of these factors, psychological or physiological, is driving SDE effects on memory.

Researchers have long been interested in determining whether consistency of physiological states during study and test phases would enhance participants' performance on explicit memory. In a study done by Miles and Hardman (1998), the authors demonstrated that matching of physiological states in study and test phases could enhance participants' abilities to recall words. Since physiological states can be objectively manipulated and measured, they are powerful variables for studying SDE on implicit memory.

Along with the variables for studying SDE on implicit memory, researchers were also interested in the type of tests that were employed in the experiments of SDE on implicit memory. The inconsistency with regard to the existence of SDE on previous implicit memory research may be a result of the use of different types of implicit memory tasks in different studies. Previous research (Parker, Gellatly & Waterman, 1999; Smith, Heath & Vela, 1990) suggests that there is an external (environmental) SDE on conceptual implicit memory tasks that require semantic processing or conceptual elaboration during the test (for example, category production). Perceptual implicit memory tasks, which rely on perceptual operation during the test (for example, word-stem-completion), in contrast, did not show environmental SDE (Jacoby, 1983; Parker, Gellatly & Waterman, 1999; McKone & French, 2001). Nevertheless, the existence of the internal SDE on conceptual implicit memory tasks remains unknown. Therefore, in order to gain more confidence about the existence of SDE on conceptual implicit memory tasks, further research is needed.

The present study sought to explore physiological SDE, instead of environmental SDE, on implicit memory when a conceptual task is used. Because physiological variables can be systematically monitored, measuring heart rate would be more objective than using self-reports to measure internal SDE on implicit memory.

We predicted that when participants were in the same physiological state during study and test, they would generate more study list words on a conceptual implicit memory test than those whose physiological states were mismatched at test.

Method

Participants

Twenty-five students (9 male and 16 female) from the University of California, Los Angeles participated in the study. Sixteen participants were enrolled in a cognitive psychology laboratory class and participated in the experiment as a requirement of the class. The rest of the participants were students who volunteered to participate in the experiment and received no compensation.

Design

The experiment used a 2 x 2 between-subjects design. One of the independent variables was participants' physiological state at study and the other independent variable was participants' physiological state at test. Participants' physiological states were manipulated at both study and test phase by being either exercise (E) or rest (R). Participants did jumping jacks when they were asked to exercise. When participants were asked to rest, they simply sat in their seats. Using this design, four groups of participants were generated; in the EE group, participants exercised in the study phase and in the test phase; in the ER group, participants exercised in the study phase and rested in the test phase; in the RE group, participants rested in the study phase and exercised in the test phase; and in the RR group, participants rested in both the study and test phases. The dependent variable was the mean number of study list words that participants generated in the test phase.

Materials

Words presented during the study phase were drawn from eight categories. Most category names and categorical words were taken from Parker, Gellatly and Waterman's (1999) study. Since the current study used only eight categories and there were only four words in each category in Parker, Gellatly and Waterman's (1999) study, an additional word was added to each category in order to increase the amount of words to five words for each category. Moreover, the current study replaced some of the high frequency words and one category name from Parker, Gellatly and Waterman's (1999) study to medium frequency words to decrease the likelihood of participants from remembering the words easily due to daily use and familiarity (See Appendix). Participants studied words from four out of the eight categories, with category type counterbalanced across conditions. Five words from an additional buffer category were also presented to all participants during the study phase. The purpose of the additional buffer category words was to prevent participants from thinking that words they were asked to generate can all be found on the study list. All category names were tested during the test phase except the buffer category name.

Words were recorded on a CD and played by a CD player during the study phase. Our measure of participants' performance was behavioral. Digital voice recorders documented participants' answers during the test phase. The measurement of participants' heart rate was physiological. Heart rate monitors measured heart rate once before the study phase, and once before the test phase.

Procedure

The physiological state manipulation procedure was similar to the procedure used by Miles and Hardman (1998). Participants underwent two minutes of rest or exercise, followed by three minutes of study phase, during which participants either continued to exercise or continued to rest while the word list was played to them. After the study phase, participants were given a three-minute period, in which all participants were told to sit down and rest quietly. After that, there were two minutes of exercise or rest depending on participants' experimental condition. This period was followed by a test phase of four minutes, in which participants kept exercising or resting while they were doing the test.

In the study phase, words from the word list were presented on a CD player. The EE and ER groups exercised while listening to the words. The RE and RR groups simply sat in their seats and listened to the word list. In the test phase, the EE and RE groups exercised while taking the test and the ER and RR groups took the test while sitting in their seats.

During the test phase, participants completed a category production test (adapted from McBride & Dosher, 2002; Besche-Richard, Passerieux, Hardy-Bayle, Nicholas & Laurent, 1999). They were instructed to produce five example words from each specified category name as quickly as possible. Participants were not required to produce the words that were presented during the study phase. They were instructed to give the first words that came to their mind. They were tested on a total of eight category names. However, only four of those category names were relevant to the words they had heard in the study lists. The buffer category name was not tested. Participants were allowed a maximum of 30 seconds to give their responses for each category name. If they were not able to generate the required amount of words within 30 seconds, experimenters would skip to the next category name. Participants' responses were recorded.

Results

As a manipulation check, a 2 x 2 between subjects ANOVA was used to analyze participants' heart rates when they were exercising and resting, during the study phase and test phase. Results revealed that the manipulation was successful, showing a significant main effect of participants' physiological states on their heart rates, such that the average heart rate of participants who exercised (*M* = 114.92, *SD* = 6.23) were significantly higher than that of the rested participants (*M* = 75.25, *SD* = 6.48), *F* (1, 46) = 973.16, *MSE* = 19642.93, $p < .01$. There was no significant main effect on participants' heart rate during study and test phase, *F* (1, 46) = 1.19, *MSE* = 23.93, $p = .28$. Participants' average heart rates during study phase (*M* = 94.39, *SD* = 6.36) were not significantly different from their average heart rates during test phase (*M* = 95.78, *SD* = 6.36; See Table 1).

The number of study list words generated by participants in the category production test was also analyzed by a 2 x 2 between subjects ANOVA. The analysis revealed a significant interaction between participants' physiological state at study phase and participants' physiological state at test phase, *F* (1,21) = 5.64, *MSE* = 58.70, $p < 0.05$.

Independent sample *t* tests were conducted to investigate simple effects. When comparing all participants who exercised during the study phase, those who also exercised during test phase (EE) (*M* = 11.14, *SD* = 2.91) generated significantly more study list words than participants who rested during test phase (ER) (*M* = 6.83, *SD* = 1.33), *t* (11) = 3.33, $p < .01$. However, when comparing all participants who rested in the study phase, the mean number of study list words generated by participants who also rested in the test phase (RR) (*M* = 9.50, *SD* = 4.32) was not significantly higher than participants who exercised in the test phase (RE) (*M* = 7.67, *SD* = 3.61), *t* (10) = -0.8, *p* = 0.44 (See Figure 1).

There were no significant main effects of the participants' physiological states at study and test phase. The mean number of study list words generated by the participants who exercised during the study phase (*M* = 8.99, *SD* = 3.23) was not significantly different from those who rested during the study phase (*M* = 8.58, *SD* = 3.23), regardless of the test conditions, rest or exercise, *F* (1, 21) = 0.1, *MSE* = 1.02, *p* = 0.76. The mean number of study list words generated by the participants who exercised at the test phase (*M* = 9.41, *SD* = 3.23) was not significantly different from those who rested at the test phase (*M* = 8.17, *SD* = 3.23), regardless of the study conditions, rest and exercise, *F* (1, 21) = .92, *MSE* = 9.54, *p* = .35.

Discussion

The manipulation check showed that the heart rate of participants who exercised was significantly higher than that of the participants who rested, regardless of whether they were in the study phase or test phase. Therefore, participants who exercised and participants who rested were manipulated in different physiological states.

The results of the participants' performance on the category production task support part of our hypothesis. Participants who exercised in the study phase and test phase (EE) presented more study list words on the conceptual implicit memory test, than participants who exercised during the study phase and rested during the test phase (ER). However, the number of study list words presented by participants who rested in the study and test phases (RR) was not significantly different from participants who rested during the study phase and exercised during the test phase (RE). Although the current study did not find a significant difference between RR and RE groups, the data shows that there is a numerical difference between these two groups. When participants rested in the study phase, participants with the same physiological states (RR) in the test generated more study list words on average than those with different physiological states in the test (RE). This numerical difference showed a general trend consistent with our hypothesis.

Miles and Hardman (1998) found that there is physiological SDE on explicit memory. In their study, participants in the same physiological states during study and test (EE and RR), recalled more words than participants who had different physiological states during study and test (ER and RE). The current study expanded on these results and tested for possible physiological SDE on conceptual implicit memory tasks (category production). The results of the current study were similar to Miles and Hardman's (1998) finding.

The current study provides further support for the notion that SDE on implicit memory exists only when conceptual implicit memory tasks are used (Parker, Gellatly & Waterman, 1999). When physiological arousal was present during the study phase, performance on the conceptual implicit memory task is better when the same level of physiological arousal is also present at test, than when the level of physiological arousal is different at test.

Previous research of SDE on memory has mainly focused on environmental (external) variables. In the limited amount of studies that addressed internal SDE on memory, the variable that they used, such as mood states, were not objective. Moreover, those studies of internal SDE have mainly focused on explicit memory. Therefore, the current study chose an internal variable (heart rate) that can be objectively measured and tested the possibility of physiological SDE on implicit memory. The result showed that physiological (internal) SDE exist in implicit memory, at least when participants were physiologically aroused. Our study also supports the suggestion that SDE exist in implicit memory while a conceptual implicit memory task was used in the experiment. This result may help to resolve the inconsistent findings of the existence of SDE on implicit memory in previous literature and implicates an appropriate direction of research in the future.

One limitation of the present study was the small sample size. Another may be participants' familiarity with the experimental paradigm. Of our 25 participants, 16 were enrolled in a psychology class in which implicit memory and SDE were discussed. Participants' possible familiarity with the premise of this study may have affected their performance.

Another possible limitation of this study may be that for some participants in ER and RE group, the change of heart rate from study phase to test phase was not large enough. In this case, some participants in ER and RE group may not feel that they were in completely different physiological states during the study phase and test phase. Although on average we found that heart rates of participants who exercised during the study phase or test phase were significantly higher than those of participants who rested during the study phase or test phase, the differences may not be large enough. For example, compared to Miles and Hardman's (1998) study, whose participants had a 60% heart rate change from rest to exercise, the participants in the current study only had about 51% heart rate change from rest to exercise. This was probably due to the lack of control of participants' exercising speed. Experimenters in this study observed that when participants were required to do jumping jacks, the speed of jumping varied between participants. In this case, the physiological states during exercise for the ER and RE participants who performed the exercise at a slower speed may not have been different enough from their physiological states during rest. This may account for better performance on the implicit memory test than others who performed rapid exercise in the same groups, and may lead to the insignificant difference between the performance of participants in the RE and RR groups.

Besides employing more participants and controlling the amount of exercise, future research should also focus on physiological SDE on different implicit and explicit learning tasks. Since most of the previous research of physiological SDE on explicit and implicit memory has used verbal learning tasks, the existence of physiological SDE on other explicit or implicit learning is still unknown. Future studies of physiological SDE on explicit learning could employ picture recognition tasks in order to investigate if the memory of pictures is better when physiological states are the same during study phase and test phase. Moreover, since current research has not compared conceptual and perceptual implicit memory tasks directly, future research comparing the existence of physiological SDE on conceptual implicit memory tasks and perceptual implicit memory tasks may be useful. By studying physiological SDE on different implicit and explicit learning tasks, we can have a better understanding of the nature of physiological SDE.

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Appendix

Word List

Insects (Buffer)

- Ladybug
- Spider
- Beetle
- Mosquito
- Mantis*

Body Parts

- Shoulder*
- Elbow*
- Chest
- Finger
- Neck*

Birds

- Parrot
- Starling
- Penguin
- Canary
- Swan*

Fruits

- Lemon
- Tangerine
- Apricot
- Mango
- Pineapple*

Mammals

- Tiger
- Giraffe
- Elephant
- Squirrel
- Hamster*

Countries

- Spain
- Japan
- Sweden
- Singapore*
- Finland*

Metals

- Bronze
- Mercury
- Silver
- Steel*
- Copper*

Flowers

- Tulip
- Buttercup
- Pansy
- Marigold
- Carnation*

*Musical Instruments**

- Flute*
- Harp*
- Cello*
- Tuba*
- Clarinet*

*Words and category name that were not included in Parker, Gellatly and Waterman’s (1999) study

Table 1.

Mean heart rate (BPM) at study and test phase for participants who exercised and rested (N = 25).

		Exercised Participants	Rested Participants
	Study Phase	114.54	74.25
Mean Heart Rate (BPM)	Test Phase	115.31	76.25

Figure 1. Mean number of words generated by participants in EE, ER, RE, and RR group.