RUNNING HEAD: UNAWARE ASSOCIATIVE LEARNING

Does Unaware Associative Learning Exist? Behavioral, Biological, and Theoretical Considerations

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This article was written in December, 2008, as the term paper in PSY 418 Learning and Cognition, Department of Psychology, Illinois State University.

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Scholars in various fields, such as psychologists, consumer scientists, and neuroscientists, have studied why people associate two events or stimuli together, which I will refer to as associative learning. To be precise, associative learning (AL) was defined as "the formation of links between mental representations of physical stimuli." (Mitchell, De Houwer, & Lovibond, in press, p. 3) Although this topic was studied in various fields for a long time, there are still debates on the nature and role of awareness in AL. Some researchers supported the idea that contingency awareness preceded AL (Lovibond & Shanks, 2002; Mitchell, et al., in press). Other researchers found the evidence in unaware association between stimuli (Pessiglione, et al., 2008). There is variation in AL studies that may make debates difficult to conclude, such as operational definition of unawareness or types of AL that researchers were interested in. From these various sources, I conclude and argue that people could learn association without awareness.

In this article, I will define awareness and clarify research paradigms in the study of AL. Next, I will provide empirical research on behavioral and biological aspects indicating that people could associate stimuli without awareness. Finally, I will show theoretical aspects of unaware AL. I will show several possible characteristics of unaware association learning that are different from and some that relate to aware association learning, as well as the role of unaware and aware AL and memory in human cognition.

Definition of awareness

Awareness may be defined as "having knowledge or realization; conscious; cognizant" ("Merriam-Webster's collegiate dictionary," 2001, p. 45). It is very difficult in transcribing this term with scientific accuracy. Because of this semantic problem, I summarize three major problems in the study of awareness in AL: distinction between awareness and consciousness, difference in parts of awareness, and differences in operational definition of awareness in AL.

First of all, the reason why I use awareness, instead of consciousness is that consciousness has two meanings. Consciousness may be viewed as level or state of consciousness. This meaning will classify unconscious people as "unresponsiveness, lack of voluntary movement and lack of any memory of conscious experience after recovery." (Tsuchiya & Adolphs, 2007, p. 159) However, another meaning of consciousness is that people know about an object or stimuli that they perceive or know the way of utilizing object or stimuli information by themselves (Tsuchiya & Adolphs, 2007). The second meaning of consciousness is the same as awareness. I will use awareness because of precision.

However, as a second problem, awareness can appear in different sources in AL. In my opinion, there are three different but connected occurrences of unawareness in AL. First, relating to unawareness in perception, people are not aware of stimuli that they receive to their cognition. This phenomenon may be called as subliminal perception awareness (SPA). For example, researchers showed a stimulus in very short duration, making people unaware of this stimulus, and followed with a masked stimulus (Both, et al., 2008). Another type of unawareness in AL is unawareness in contingency, which I will refer to as contingency awareness (CA). People may not be aware that there were associations between stimuli, whereas their behaviors indicate they, perhaps, learned this association. For example, people associated faces and words implicitly (Degonda, et al., 2005). Lastly, people may be unaware of their action in response to stimuli in

AL. For example, people could increase their skin conductance after shocking without awareness (Carter, O'Doherty, Seymour, Koch, & Dolan, 2006). The action unawareness has already shown that it did exist and was referred to as involuntary action in the literature (Hershberger, 1989). These three different types are related. If people associate subliminal stimuli with other stimuli, people should not know CA. However, contingency unawareness may appear without SPA, such as sequence learning (Koch, 2001). The complexities of this issue will be shown later.

Now I will address the last problem: How do we know people are really unaware of stimuli, contingencies, or actions? This question resulted in the debate in operational definition of unawareness. Lovibond and Shanks (2002) proposed that unawareness AL usually measured from self-reported of unawareness while behavioral responses changed. They argued that the results of unawareness reports had to include four related characteristics, to be precise that people were really unaware of AL. First, the self-report had to be relevant to information in the AL tasks that participants did. For example, when the tasks of association used the flavor and the colored water, researchers had to show these stimuli in measuring the awareness. Second, the self-report had to ask sooner after participants formed behavioral changes. Third, the self-report had to be sensitive to detect awareness. For example, if the measure of unawareness was only asking without any cue information of AL task, this measure was based on recall. This measure was not similar to the task that measured changing in behavioral responses, which was based on recognition. Lovibond and Shanks (2002) argued that the self-report had to be based on recognition, instead of recall. Last, participants should be active in reporting awareness from the stimuli that people associated. For example, researchers showed subliminal stimuli and asking the probability of the following associated stimuli.

I agree with these criteria; however, I do not agree that these criteria can be applied for all types of AL. For example, if people are not aware of subliminal stimuli, they cannot know contingency awareness as well, which were supported by some previous studies (Both, et al., 2008; Pessiglione, et al., 2008). Therefore, testing awareness of subliminal stimuli is enough. In sum, the problems of awareness definition are complex and may be the source of incongruence in research results. However, this problem was not the only source of researches incongruent results incongruence, differences in tasks of AL is another source also.

Types of study in associative learning

Researchers make different tasks to draw different conclusions. From the selective research articles, I divided AL tasks into four categories: simple association task, sequence learning task, evaluative learning task without SPA, and evaluative learning with SPA. All of these tasks examine CA, but a simple association task and evaluative learning with SPA also examine SPA. Some empirical researches used involuntary behaviors in determining CA such as simple association task. The first two categories are not involved in the evaluative values, while the last two categories are involved the evaluative values that associate with emotion. These researches are summarized in Table 1.

Simple association tasks

This task is found in Degonda and her collegues (2005) research. In this task, they show faces and words about occupation in both subliminal and supraliminal screen. They divided participants into four groups. Participants in the first group were given incongruent information.

For example, in subliminal tasks, a face was associated with magician, but the same face was associated with biologist in supraliminal tasks. Participants in the second group were given congruent information but not exactly the same. For example, a face was related to jurist in subliminal tasks but lawyer in supraliminal tasks. These words came from the same categories of occupation. Participants in the third group were given exactly the same stimuli in subliminal and supraliminal tasks. Lastly, the fourth group is control group; participants did not receive subliminal stimuli. This task determined that participants in the first group had a harder time associating supraliminal faces and words than participants from second, third, and fourth group. However, the performance in retrieval tasks showed the impact of implicit learning but in an opposite direction. Participants from all three experimental groups recalled the learned associations worse than participants in the control group.

Sequence Learning Tasks.

There are two types of AL tasks that can be classified as sequence learning task: task-switching paradigm (Koch, 2001) and number reduction tasks (Rose, Haider, & Buchel, 2005; Yordanova, et al., 2008). In the task switching paradigm, participants responded to the large or small “A” or “4” that appeared on the screen in red or blue within a rectangle. Around the rectangle, there were cues that told participants which rules were used in these stimuli: form (F), color (C), or size (S). In the screen, participants were shown a cue, followed by a stimulus. Next, participants had to press the left or right key corresponding to the cue and stimulus. The cues were shown in a fixed sequence, such as FSCCSSFFC. Participants answered through this sequence for many times, which made reaction time in responding stimuli and cues decrease. After that, researchers changed the sequence. Koch (2001) found that participants responded

slower than the original sequence, which meant that participants learned the original sequence. Koch also found that almost participants were not aware of the implicit sequence or the sequence shift.

In the number reduction task, as shown in Figure 1, participants saw the computer screen which showed the sequence of numbers which were only three possible digits: 1, 4, or 9. Participants had to make the new set of seven numbers from the provided sequence. The first answer in the new sequence would use the first two number of the provided sequence. The second to seventh answers would use the previous answer, which were the first to sixth answers, respectively, and the next number of the provided sequence that had not used in determining the previous answers, such as the third number for determining the second answer. Participants had to answer until reaching the seventh answer. The answers which participants had to press on the keyboard of computer were based on two rules: identity and difference rules. When the two numbers were the same, such as 1 and 1, the identity rule was used; participants had to answer the same number, which is 1. However, when the two numbers were different, such as 1 and 4, the difference rule was used; participants had to answer the rest of possible numbers, such as 9 in this example. After answering the seventh answer of the set, the new set would appear on the computer screen. Also, researchers asked participants to respond as quickly as possible and the reaction times in each respond after appearance of the question were measured.

All sets of answers were generated in the underlying common regularity. The fifth, sixth, and seventh answers in each set were the same as the fourth, third, and second answers. In other words, there was a mirror structure of answers for each sequence. The last three responses mirrored the preceding three responses. If participants had already known the regularity of this task either implicitly or explicitly, the response time of last three answers would decrease from

the response time of the previous four answers. In testing whether participants learned this regularity, researchers changed the last digit to violate the mirror rule, after participants had responded to these tasks for many times. Rose et al. (2005) showed that participants responded slower when the last digit was changed, which could imply implicit learning. In sequence learning tasks, there are two sources of unawareness: contingency unawareness and involuntary action.

Evaluative Learning without Subliminal Perception Awareness.

This task involved in relating stimuli with rewards or punishments. The only source of unawareness in this task is CA. A lot of researchers proposed that conditioning in humans occurred only when participants were aware of contingency relationship (De Houwer, Thomas, & Baeyens, 2001; Lovibond & Shanks, 2002; Mitchell, et al., in press). However, there are some researchers that contradict this proposition, especially in color-flavor association (Baeyens, Eelen, Van der Bergh, & Crombez, 1990; Dickinson & Brown, 2007; Wardle, Mitchell, & Lovibond, 2007). I will discuss only this contradictory task. In this task, participants drank the water of sugar (palatable taste) or tween (unpalatable taste) that were colored as blue, green, yellow, or red. After participants learned these associations of color-flavor, participants were introduced new drinks. These drinks were added banana, chocolate, vanilla, or lemon flavors. The participants were divided into two groups. The participants in the first group drank the water with either the sugar or tween, which was predictable by both color and added flavor. The color associations were the same as old drinks. However, participants in the second group drank the water with sugar or tween, which was predictable by only added flavor. The color associations were different from the old drinks. Dickinson and Brown (2007) found that participants rated the

added flavor that related to sugar better and rated the added flavor that related to tween worse. However, participants were not aware the added flavor-sugar or added flavor-tween contingencies. On the contrary, Wardle et al. (2007) showed that participants changed their rating to added flavor, only when they were aware of these contingencies. These different results may be come from different designs and measures of awareness. I will explain in next section.

Evaluative Learning with Subliminal Perception.

This task is similar to the previous task, but the stimuli that were used to associate with rewards or punishments were subliminal. There are two research studies which will be considered here. One related to Pavlovian conditioning (Both, et al., 2008), another related to operant conditioning (Pessiglione, et al., 2008). In the first research, two sexual-related pictures were introduced to participants subliminally. Only one stimulus was associated with genital vibrotactile stimulation. After participants received picture-stimulation contingency for many times, they were shown only subliminal picture, without stimulation as the test of AL. Both et al. (2008) found that the vaginal pulse responded higher with associated picture than unassociated picture. However, there are no statistical differences in skin conductance measures and subjective ratings of liking in these two pictures. In operant conditioning tasks, participants were shown three subliminal stimuli that were associated with rewards (+£1), punishments (-£1), or nothing. The chances that participants received rewards or punishments after each type of stimuli are 50 percent. After participants saw each subliminal stimulus, they would see word “GO” in the screen. They judged whether they betted or not. If they betted, they would receive the rewards or punishments, in 50 percent chance, which were based on the subliminal stimulus shown. Pessiglione et al. (2008) found that although participants could not detect subliminal

stimuli, they would bet on gaining subliminal stimulus more than losing subliminal stimulus for 20 percent after ten trails. In addition, when researchers showed associated stimuli supraliminally, participants prefer the gaining stimulus to the losing stimulus.

Although the research cited here is not exhaustive list of research on relating awareness and AL, these current studies have revealed that people could detect subliminal stimuli. In addition, most research indicated that people could learn association without CA. In the next section, I will combine these research results together and provided the biological evidences which supported that people could learn without SPA and CA.

Empirical results of unawareness associative learning

In this section, I will summarize the evidence of unawareness that is associated with AL. I will divide the evidence by the forms of awareness: SPA and CA. This separation is associated with different previous research results and debates in different kinds of relationship between awareness and AL. In addition, I also provided the existence of implicit memory that answered how people uphold the unaware AL in their cognition.

Subliminal Perception Awareness

There are two different types of subliminal perception that I will provide in this section: objects and emotion. These two types of perceptions are the elements in AL. Objects can be used as conditional stimulus (CS) in evaluative learning or elements in simple association tasks. Emotion perception can be used as unconditional stimulus (US) in evaluative learning.

Several research studies have shown that people could perceive subliminal objects (Both, et al., 2008; Degonda, et al., 2005; Pessiglione, et al., 2008). For example, Pessiglione et al. (2008) found that participants preferred the subliminal stimuli that were associated with rewards and punishments by rating scales. They also compared the brain functioning by fMRI and found that individual performance on AL related to extrastriate visual cortex which associated the ventral occipitotemporal stream of visual perception. The authors inferred this brain region as the participants' performance in discriminating different subliminal stimuli, in contrast with intra-individual performance which associated with AL.

In addition to subliminal object perception, people can receive emotional characteristics of these objects also. Jiang and He (2006) showed the participants both supraliminal or subliminal faces with neutral or fearful emotions. The subliminal faces were the original faces that flashed at random patterns called Mondrian images. They found that amygdala responded more to fearful faces than the neutral faces in both supraliminal and subliminal conditions. Pessoa (2005) proposed that there were two tracks in perceiving emotion from visual stimuli to amygdala: cortical and subcortical pathway. The cortical pathway associated with supraliminal perception of emotion, which was related to occipital lobe and inferotemporal cortex. The subcortical pathway associated with unaware perception of emotional stimuli, which was related to superior colliculi and pulvinar. The subliminal emotional stimuli affected not only recognition of stimuli, but also motivated behavior (Tsuchiya & Adolphs, 2007); for example, drinking behavior increased after seeing subliminal happy faces.

Therefore, the perceiving of subliminal stimuli was strongly supported by empirical studies from behavioral and biological domains. These investigations showed the incongruence

between representation at the brain level and explicit memory in behavioral level. However, next section will show you another form of this incongruence.

Implicit Memory

Implicit memory means that people store memory in the brain without conscious awareness about this memory. Daselaar, Fleck, Prince, and Cabeza (2006) studied this phenomenon by distinguishing old words, which participants saw before, and new words. There are four possible outcomes of this task: a seen word that was classified as old (hit) or new (miss), and an unseen word that was classified as old (false alarm) or new (correct rejection). Surprisingly, posterior medial temporal lobe activated in the hit and miss outcomes more than the false alarm and correct rejection outcomes. In other words, this brain area could classify actually old and new words without people's awareness. I am not sure whether this brain activation occurred in every seen word. If it was not, this phenomenon might be explained in another framework. That is, why did some of the words associate with brain activation, and why did others not associate? However, this research finding provided another explanation in the inconsistent results of the role of CA in evaluative learning without subliminal stimuli. Also, it provided the possibility that implicit knowledge resulted from unaware AL could be stored in human cognition as implicit memory.

Contingency awareness

In the section of types of learning in the AL studies, I explained that most of AL works supported that humans could learn association without awareness, except works in evaluative

conditioning without subliminal stimuli. I will explain a brain function that associates AL without CA first, and then the inconsistent finding.

The neuroimage findings found that both aware and unaware AL related to similar brain areas. Different tasks of AL associated with different brain areas. In simple association tasks, which both faces and occupation words were subliminally presented to participants, hippocampus activated in the implicit association via subliminal stimuli (Degonda, et al., 2005). Researchers have known that the hippocampus was associated with explicit episodic memory (Rolls, 2000). This research showed that the hippocampus activated for implicit association as well. In the number reduction task, which was one of the sequence learning task, Rose et al. (2005) found that right ventrolateral prefrontal cortex activated when the last digit of this task violated from the hidden rule. This finding was congruent with premotor action plan in flanking tasks (Hazeltine, Poldrack, & Gabrieli, 2000). In this task, participants were shown the three colored circles on the screen. Participants responded to the color of center circle without being interested in flanking circles: left click on red or green and right click on blue or yellow. There were two kinds of these circles sets: congruent and incongruent sets. In the congruent set, participants were shown two flanking circles in different colors but still using the same hand in response, such as red-green-red or yellow-blue-yellow, while, in the incongruent set, they were shown the color that use a different hand to respond, such as red-yellow-red or blue-green-blue. In incongruent tasks, Hazeltine et al. (2000) found that the right ventrolateral prefrontal cortex was active, as the number reduction task research. Pessiglione et al. (2008), as the last evidence shown here, also found the brain functioning in their evaluative learning with subliminal tasks similar to evaluative learning with SPA and CA. If participants practiced more, the number of correct responses to subliminal stimuli increased and the ventral striatum activation also

increased as well. Researchers had shown that ventral striatum or dopamine-related system related to reward-learning systems (Rolls, 2000). These three findings showed the congruent evidence about the existence of AL and the brain areas were similar to AL with awareness.

Although the behavioral- and biological-based findings have shown the existence of AL without CA in simple association tasks, simple sequence learning task, and evaluative learning with subliminal stimuli tasks, the most empirical findings have found that evaluative learning without subliminal stimuli tasks required CA (Lovibond & Shanks, 2002; Mitchell, et al., in press). The only task in evaluative learning without subliminal stimuli that found no relation between CA and AL was color-flavor conditioning, which was described above. Moreover, the color-flavor conditioning research led to incongruent findings. Some researches revealed no correlation between CA and AL (Baeyens, et al., 1990; Dickinson & Brown, 2007), but some researches revealed the relation (Wardle, et al., 2007). In addition, Wardle et al. (2007) reanalyzed the data from Dickinson and Brown research and found the relationship between CA and AL. Therefore, Wardle et al. concluded that evaluative conditioning required CA. Although their claims made for a very strongly supported argument, I have another explanation to support the no relationship between CA and AL.

Initially, I hypothesized that it was possible that unaware evaluative learning had weaker effects compared to aware evaluative learning. There were two empirical supports for this argument. First, I will compare between Pessiglione et al. (2008) and Pessiglione, Seymour, Flandin, Dolan, and Frith (2006) works. These two studies use the same research paradigms about gambling; however, the only difference in these two studies was the use of subliminal CS (Pessiglione, et al., 2008), and supraliminal CS (Pessiglione, et al., 2006). In supraliminal CS, participants were aware of the contingency between CS and rewards or punishments. The

probabilities in responding to stimuli corresponding to rewards and punishments were 90% and 10%, respectively; however, the probabilities in subliminal CS were 60% and 40% respectively. Another finding that supported my argument was the reanalysis of Wardle et al. (2007) on Dickinson and Brown (2007) work. In simple effect analysis in the unaware group, they claimed that there was not a significant effect of evaluative conditioning because the probabilities of making type I error was greater than .05, so they rejected the existence of evaluative conditioning without CA. However, I found that it was a marginal effect (p = .076) of unaware group. They use a .05 cutoff, despite the number of people is only 20, which require the Cohen's d effect size of 0.66 to achieve the power equal to 80% (Cohen, 1988). Because of lack of power of this analysis, I, therefore, argued that there was real evaluative learning in the Dickinson and Brown work. Therefore, the most research which revealed no relationship between CA and AL might expect the evaluative learning results similarly between aware and unaware condition, in spite of the dissimilarity that I proposed.

Secondly, the incongruent research conclusion may come from different experimental design. For example, the Dickinson and Brown (2007) and Wardle et al. (2007) found the different research findings. It may result from Dickinson and Brown (2007), which I explained the experimental procedure above, use pretraining period, matching color and sugar or tween before mixing other flavors, but Wardle et al. (2007) did not use this pretraining period. The pretraining period made participants associate color and tween or sugar contingency and neglect other flavors and tween or sugar contingency. This process that learned association hindered the new association was called blocking effect (De Houwer, et al., 2001).

Finally, I think that researchers should not conclude the relationship between CA and AL if CA was not manipulated. In most research, the CA and evaluative learning results were both

dependent variables. Therefore, there may be unexpected explanation that account for the correlation between both of them. For example, participants attributed their contingencies between CS and US by using information of evaluative learning results. Although, Wardle et al. (2007) claimed that this attribution might not occur because the experiment 2B in their work found that participants found the relationship between color and sugar or tween, but they did not change their evaluation on color. I argue that there might be other explanations of these relationships because of not manipulating CA. I think that the implicit memory paradigm in previous section can be used for manipulation of CA (Daselaar, et al., 2006). Initially, participants may be aware of contingencies of CS and US in most of research paradigms in evaluative learning without subliminal stimuli. However, if leaving time for an hour or a day without recognizing CS-US relationship, the explicit memory of these contingencies may be deteriorated but the implicit memory still works.

Because of these reasons, I argue that humans really learn associations between stimuli without awareness. However, my argument leaves a lot of research questions that require clarification before making this argument with confidence. In next sections, I will explain how unaware and aware AL match with the basic ideas of human cognition. How do people use their unaware and aware AL in interacting with environment? To explain, I divide into two parts. First, I will describe the characteristics of unaware AL and relationship with the explicit memory. Next, I will describe the role of unaware and aware AL in human cognition.

Characteristics of unaware associative learning

Although unaware AL exists, the characteristics of unaware AL are not the same as aware AL. I have discussed about the different performance of unaware and aware AL in the CA section. There are four additional characteristics of the unaware AL, in my opinion.

As the second characteristic, unaware and aware AL were different in effort using. People did not use much effort in automaticity of cognition (Bargh & Chartrand, 1999). Therefore, we did not use much effort in obtaining unaware associative learning or recalling it. Moreover, we have already discussed that people really did not know what they obtained in their memory or really did not know the existence of the implicit memory. By contrast, people use much effort to obtain aware AL and know their explicit memory.

Moreover, interestingly, people may maintain both implicit and explicit memory, despite contradiction. Proposed as the dual process model of attitudes, Wilson, Lindsey, and Schooler (2000) argued that, when people learned the new association, the new association did not replace the old association. However, the new association would override the old association, which might make the implicit memory or implicit attitudes. Therefore, this contradiction made us really unclear about the role of both kinds of memory.

In addition to the incongruent coexistence, unaware AL may facilitate or block the aware AL performance. In Degonda et al. (2005) research that I described before, the results revealed that participants in incongruent groups felt it harder to encode supraliminal association tasks than participants in congruent, identical, and control groups. However, participants who had seen subliminal stimuli (incongruent, congruent, and identical groups) retrieved the association from supraliminal tasks worse than participants who had not seen (control group). Although the interaction between unaware and aware AL are still unclear, this research showed the interaction between them.

Finally, explicit and implicit memory can be transformed to each other. As shown in the Daselaar et al. (2006) finding, explicit memory could deteriorate to be implicit memory by forgetting. Also, implicit memory can shift to explicit memory. Yordanova et al. (2008) divided participants into two groups: early-sleep group, which were rich of slow-wave sleep, and late-sleep group, which were rich of rapid eye movement stage. They showed that the participants in the early-sleep group were explicitly aware of implicit hidden rule in number reduction tasks, but the participants from the late-sleep group were not aware of the hidden rule. However, this research had alternative explanations for the evidence of the shift of memory, because the two groups of participants did not differ in only slow-wave sleep and rapid eye movement stages. For example, the two groups might differ in participants' alertness or circadian rhythm.

To conclude, the unaware and aware AL have different characteristics, such as differences in performance and effort required. People could hold both unaware and aware AL, in spite of contradiction. Unaware and aware AL could be facilitate or hinder each other. They could shift to each other also. However, this coexistence of both types of AL leaves an important question. How do unaware and aware AL synchronize with the mechanism of human cognition?

Role of Unawareness Association Learning and Memory in Human Cognition

Now, there are still debates on what is the mechanism of human cognition, such as the role of automaticity in human cognition (Bargh & Chartrand, 1999). To answer this question, I will introduce the theory of controlling distal events (Jordan, 2003), which related to two types of control, aware and unaware control, in human cognition. This theory was allowed the role of

unaware and aware AL to coexist. In this section, I will explain this theory and explain why I think that this theory was fit with the coexistence of memory.

Initially, Jordan (2003) showed that, in interacting with environment, people both regulated their distal events in the external environment, which I will refer to as aware control, and regulated or constrained their internal environment, such as controlling their actions, which I will refer to as unaware control. In aware control, we made a lot of actions to regulate their distal events that involved the unaware control of actions. What we really being aware of was the changing in the distal events, not the characteristics of their actions. People did not really know their actions, as referred to as involuntary actions in Hershberger (1989). For example, a person typed the word document in their computer. What this person really regulated was the text on their document. This person was not aware of which fingers he or she pressed in the keyboard. This example revealed two types of control. Aware control, which Hershberger (1989) called voluntary actions, was the control of text in the document or the distal event. Unaware control is the internal process in this person that constrained their involuntary behaviors to make the text changing, which was typing the keyboard.

I argued that involuntary actions involved in use of implicit memory. The implicit memory would make the involuntary actions more effective. For example, task-switching paradigm (Koch, 2001) might be viewed as involving two-level of control and using the implicit memory to facilitate involuntary behaviors. People explicitly controlled the length of reaction time to be as least as possible, as aware control, and constrained the left and right hands to response from cues and stimuli, as unaware control. Koch shown that, in long cue-stimulus interval, people would use the cues to predicting the upcoming events, so they did not change their reaction time when researchers changed the sequence. However, in the short cue-stimulus

interval, participants could not use cue to predict the upcoming event, so they used the implicit memory of sequence to predict the upcoming event instead. Thus, when researchers changed the sequence, they showed delay in their reaction time.

Not only people use implicit memory to facilitate their involuntary actions, but, in my opinion, people will use the explicit memory, when people are really aware of their action or they attend to their actions. That is, people shift from involuntary action to voluntary action, such as they intentionally tracked their action. McConnell, Strain, Rydell, and Mackie (2008) research supported this idea. They randomly classified people into two groups: clear and unclear distinction about stereotypical social cues, such as appearance (beautiful vs. ugly) or ethnicity (European Americans vs. African Americans). They showed that people in the clear distinction group used implicit memory or implicit attitude to associate with particular social cues, but people in the unclear distinction group used explicit memory or explicit attitude in their judgments. In other words, when there was unclear distinction between social cues, people would use the aware or intentional action by thorough investigation in making distinction, so explicit memory was used. However, when there was clear distinction, people would use the unaware or automatic action to discriminate, so implicit memory was used.

Conclusions

There were some arguments about the role of awareness in AL, especially CA. In this article, I provided the empirical findings that provide behavioral and biological evidences that supported the existence of unaware AL. In addition, I also provided several reasons why incongruent findings occurred. As the most important reason, unaware AL performance is less

effective than aware AL, but some researchers expected the equal performance; therefore, there were incongruent research findings. Moreover, I provided the characteristics of unaware AL, the nature and the relationship between unaware and aware AL. I also suggested that the two-level model of control in human cognition may be useful to explain the role of aware and unaware AL. People used the implicit memory when they were unaware of their action or used involuntary behaviors. However, if people were aware of or intentionally tracked their actions, they used the explicit memory of association.

Although this article tried to settle down the debates of unaware AL existence, paradoxically, this article also provided more questions about details in aware and unaware AL. First, although the two-control model of cognition was fit with the existence of both aware and unaware association learning and memory, the explanation of this model about the interaction between aware and unaware association learning were still unclear. For example, this model did not answer why aware and unaware memory facilitated or hindered each other. Second, the implicit and explicit memory from aware or unaware AL did not match the model of declarative and procedural memory which previously meant as explicit and implicit memory. Implicit memory in this article has been shown that it was more than the motor learning in procedural memory. Therefore, the redefinition of implicit memory in this model should take place. Moreover, according to Koch (2001), the implicit memory could switch how they interact with the external environment. This memory could choose whether using implicit memory to predict the environment or cues in environment. This finding meant that people could control whether they used implicit memory. How people use implicit memory is still a large question for the future research. Finally, from the existence of unaware AL, I think that behavioral scientists may solve some topics that were not settled down at the moment, such as gut feelings (Pessiglione, et

al., 2008), common sense (Sternberg, Wagner, Williams, & Horvath, 1995), or insights (Wagner, Gais, Haider, Verleger, & Born, 2004). These hypothetical constructs might involve with the role of unaware AL or automaticity of behaviors.

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Table 1

Summary of selective empirical researches in the role of awareness and associative learning

Empirical Researches	Task	Source of Unawareness	Unawareness Measure	Result
Degonda et al. (2005)	SAL	SPA, CA	Testing accuracy in detection subliminal stimuli	Found
Koch (2001)	SL	CA	Interviewing whether noticing task sequences	Found
Rose et al. (2005)	SL	CA	Rate the presence of regularities	Found
Yordanova et al. (2008)	SL	CA	Questionnaire about hidden task structure	Found
Baeyens et al. (1990)	EOS	CA	Rating contingency between CS and US	Found
Dickinson and Brown (2007)	EOS	CA	Rating contingency between CS and US	Inconsistent
Wardle et al. (2007)	EOS	CA	Rating contingency between CS and US	Not Found
Both et al. (2008)	EWS	SPA, CA	Testing accuracy in detection subliminal stimuli	Found
Pessiglione et al. (2008)	EWS	SPA, CA	Asking to explain the subliminal cues	Found

Note. SAL = Simple association task; SL = Sequence learning; EOS = Evaluative learning without subliminal stimuli; EWS = Evaluative learning with subliminal stimuli; SPA = Subliminal perception awareness; CA = Contingency awareness; CS = Conditional stimulus; US = Unconditional Stimulus

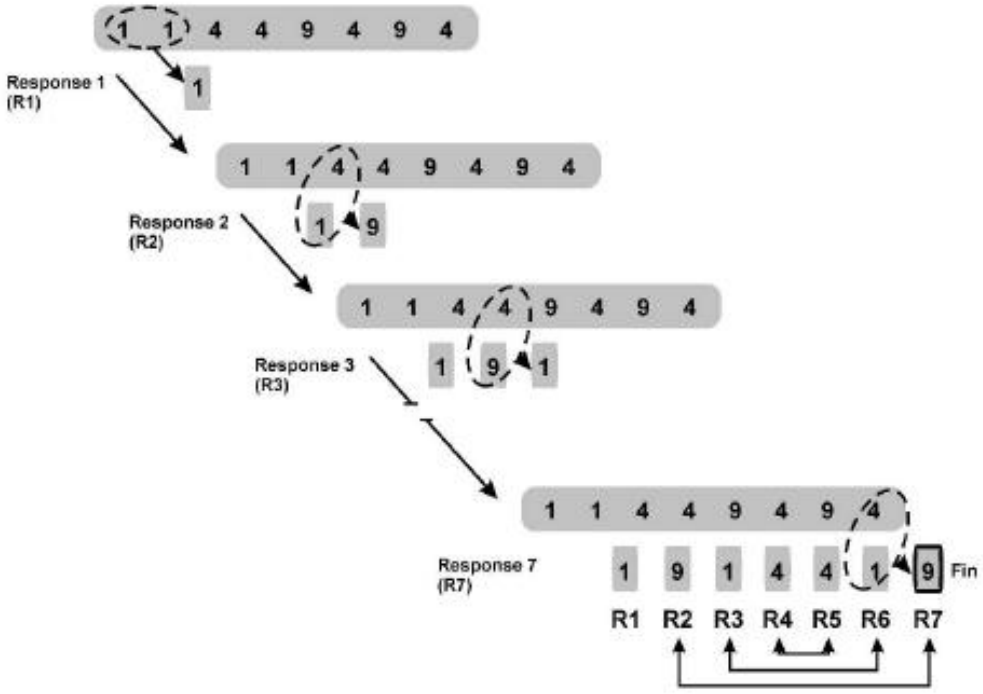

Figure 1. The number reduction task (NRT) procedures were illustrated by an example trial. Participants were seen a sequence of numbers (with only three possible digits: 1, 4, and 9) and had to make the new sequence, which contained seven numbers, paralleled to sequence shown. The answers were based on two rules: identity and difference rule. The identity rule was used when participants saw the two same numbers, such as the response 1 shown above; participants had to press the same number from the questions in the sequence, which was 1 in the response 1. However, the difference rule was used when participants saw the two different numbers, such as response 3 shown above; participants had to press the digit to make three numbers fulfilling 1, 4, or 9, which was 1 in the response 3. The hidden regularity is that the responses of answers 5, 6, and 7 were as same as the responses of answers 4, 3, and 2, respectively. Source: Yordanova et al. (2008)