The Effects of Goal Motivation on Implicit Sequence Learning

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Abstract

Implicit learning has been thought to be unaffected by intentions, yet recent studies suggest that it may be improved by goal pursuits (e.g., Eitam, Hassin, & Schul, 2008). This effect occurs even though the trigger for goal motivation is unrelated to the learning task at hand. These studies did not use clearly implicit tasks. The present study examined whether implicit learning is enhanced by priming the goal of achievement, even when explicit knowledge is eliminated. Implicit learning was assessed using an alternating serial reaction time (ASRT) paradigm, in which sequential dependencies exist across non-adjacent elements (Howard & Howard, 1997). In this task, implicit sequence learning is measured via trial-type effects (the accuracy and response time difference between predictable and unpredictable events), and explicit learning is ruled out via sensitive recognition measures. Prior to the ASRT, Goal and Control groups were given a word search task which did or did not contain achievement-related words. Overall, implicit sequence learning was not enhanced by priming the goal of achievement; both groups showed systematic and similar learning. The only exception was that on Epoch 3 (of the 9 epochs presented) the Goal group showed significantly more learning than Control. These findings suggest that if there is a goal motivation effect on implicit learning, it is transient and short-lived.

*Keywords*: Implicit learning, priming, goal motivation, alternating serial reaction time task.
The Effects of Goal Motivation on Implicit Sequence Learning

Implicit learning has an intrinsic role in regulating human behavior by adapting one’s responses to the rhythm of environmental conditions. This kind of learning reflects the tendency for people to become attuned to features of diverse and dynamically changing conditions by learning regularities in the stimulus structures and the complex relations among events that characterize the environment (Reber, 1967, 1989; Seger, 1994). The hallmark of implicit learning is that it proceeds in an incidental manner such that people have no conscious knowledge of what they have learned even though they demonstrate improvements on their performance of a task with practice (Cleeremans, 1993; Frensch & Runger, 2003). Despite the range and complexity of cognitive processes involved in implicit learning, little is known about how such learning can be maximized.

Given the limited capacity of our conscious cognitive resources (Baars & McGovern, 1996), it is not surprising that automatic and unconscious mental processes facilitate our active exploration of and interaction with objects in novel environments (Lewicki, Hill, & Czyzewska, 1992). Much research has investigated the role of implicit processes underlying our feelings, attitudes, and actions (Bargh & Chartrand, 1999; Gilbert, 1991; Shiffrin & Schneider, 1977; Wilson & Schooler, 1991; Zajonc, 1980). Since human behavior is shown to be largely driven by goals (Aarts, Custers, & Holland, 2007; Aarts & Dijksterhuis, 2000; Custers & Aarts, 2005), investigating the implicit mechanisms underlying goal pursuit is of particular importance for understanding human consciousness and cognition. Empirical studies have revealed that priming effects can trigger an achievement goal independently of intent or awareness, and that goal attainment is mediated by the tendency for active goals to process relevant information in complex environments (Bargh & Gollwitzer, 1994; Bargh, Gollwitzer, Lee-Chai, Barndollar, &
Trotschel, 2001; Bargh, Green, & Fitzsimons, 2008; Hassin, Bargh, & Zimerman, 2009). For example, Bargh et al. (2001) primed participants with the goal of achievement using achievement-related words embedded in a word search puzzle and found that the priming manipulation subsequently fostered improvements in performance on five different unrelated experimental tasks. Therefore, priming research has provided new insight into the subtle yet robust effects of unconscious processes involved in motivating a person’s actions.

Traditionally, implicit learning was thought to involve a passive, unselective learning process that is driven exclusively by the ability for people to adapt to pattern variations in the external environment without intention or awareness (Reber, 1967, 1989; Seger, 1994; Whittlesea & Wright, 1997). Unlike conscious and deliberate explicit forms of learning that proceed in a goal-directed fashion (Cohen & Squire, 1980), implicit learning was assumed to be unaffected by a person’s will to learn since it entailed an effortless acquisition of knowledge without any conscious control. Moreover, researchers assumed that the human propensity for abstracting information about the properties of their evolving environments occurred regardless of the relevance of these structures to the individual’s goals (Hayes & Broadbent, 1988; Lewicki et al., 1992).

Yet, a recent study by Eitam, Schul, and Hassin (2008) demonstrated that priming the goal of achievement using a word search puzzle containing hidden achievement-related words enhanced implicit learning on a serial reaction time (SRT) task, even though the trigger for the goal motivation was unrelated to the task at hand. The SRT task they used consisted of 4 training blocks followed by 3 test blocks, in which each block was 50 trials long. In each training block, a 10-element fixed sequence was repeated five times. The fixed sequence used during training was then introduced in the middle (i.e., second) test block. Learning was measured during the test
blocks as the average response time (RT) difference between the first and third random blocks and the second fixed-sequence block. Their results showed that learning was significantly greater in the goal-priming group than the control group, and that there were no significant group differences in average RT for random blocks (i.e., performance on the random blocks was unaffected by the priming procedure). In addition, there were no significant differences between goal-primed and control participants’ explicit motivation to perform the SRT task or in their explicit knowledge of the sequence structure. Based on these results, Eitam et al. (2008) argued that nonconscious goal pursuit (NCGP) facilitated goal attainment by enhancing the probability of learning goal-relevant structures in unfamiliar environments. They proposed that implicit learning is a motivated process that emerges only for goal-relevant dimensions (Eitam et al., 2008; Eitam, Schul, & Hassin, 2009). Furthermore, they posited that motivational states may enhance the efficiency and accuracy with which people are able to learn the structure of novel environments by modulating selective attention according to prioritized goal-relevance of the structures (Eitam et al., 2008; Eitam et al., 2009; Jimenez & Mendez, 1999; Posner, 1980).

The present study examined the effects of goal motivation on implicit sequence learning. The main objective was to replicate Eitam et al.’s (Experiment 2; 2008) results by using a clearly implicit task and ruling out explicit learning. Since the reaction time data presented in the prior study did not permit one to see data from the early part of their training, the course of sequence learning itself could not be examined. Furthermore, learning was not necessarily implicit since participants showed some evidence of explicit knowledge. The present experiment used the same goal motivation procedure and tests of explicit achievement motivation as Eitam et al. (2008). As the word search (WS) task used in Eitam et al.’s (2008) study was in Hebrew, Goal and Control groups were given the original WS task invented by Bargh et al. (2000) which does or does not
contain achievement-related words. The SRT task used in the prior study was replaced with the alternating serial reaction time (ASRT) task. In addition, explicit learning was ruled out via more sensitive recognition measures. An additional change that was made to Eitam et al.’s (2008) procedure was that a word recall component was added to assess explicit memory for the list of words used in the word search (WS) task.

The ASRT task used in this experiment is believed to be a superior instrument for measuring pure implicit sequence learning since it follows a second-order structure, instead of the regularity of first-order patterns of the SRT. Consequently, people are less likely to be consciously aware of the underlying pattern embedded in the experimental blocks and even less likely to be able to describe it. The course of learning for the ASRT is examined by analyzing mean accuracy and mean of median reaction time measures separately, on each block for each participant. Implicit sequence learning is measured via trial-type effects (i.e., the accuracy and reaction time difference between predictable and unpredictable events). It is predicted that trial-type effects will be larger for the Goal group than the Control, with neither group explicitly aware of the regularity. Therefore, this study aims to demonstrate that implicit learning is enhanced by priming achievement goals even when explicit knowledge is eliminated.

**Method**

**Participants**

Twenty-four Georgetown University students (20 Females and 4 Males; Mean age: 21.1 years) participated in the experiment for course credit or pay. Participants were tested individually and randomly assigned to one of two conditions: Goal (3 Males, 8 Females; Mean age: 21.4 ± 1.3 years) or Control (1 Male, 12 Females; Mean age: 20.8 ± 1.0 years).
Procedure

Upon arriving at the lab, participants signed an informed consent form approved by the Georgetown University Institutional Review Board. They then completed a biographical and a health screening questionnaire. Next, they were told that the experimental session consisted of two parts. The first required them to complete a word search (WS) task (described below). After finishing the WS, they completed three consecutive sessions of the alternating serial reaction time (ASRT) task in the same visit. A rest break of at least 5 minutes was given between sessions for the ASRT. At the end of the experimental session, participants were administered tests of explicit awareness of the ASRT sequence including a card sorting task, interview, and sequence generation task. Then, participants filled out a questionnaire which assessed their explicit motivation to perform on the ASRT, awareness of the goal priming procedure, and their ability to recall words from the word search task.

Apparatus

Word search (WS) task. Participants completed a paper-and-pencil word search puzzle (Bargh et al., 2001), and the time taken from start to finish was recorded. The puzzles consisted of a $10 \times 10$ array of letters in which participants had to search and circle 13 target words that were listed alphabetically underneath the puzzle (Appendix A and C). In the Goal condition, 7 of these words were achievement-related (achieve, attain, compete, master, strive, succeed, and win). In the Control condition, these words were replaced by motivationally neutral words (carpet, hat, ranch, river, robin, shampoo, and window). The remaining 6 words were common to both conditions (building, green, lamp, plant, staple, and turtle). After completing the task, participants were asked to rate the difficulty of the task from 1-4 (1 being ‘Easy,’ 2 being ‘Somewhat Easy,’ 3 being ‘Somewhat Difficult,’ and 4 being ‘Difficult’).
Alternating serial reaction time (ASRT) task. Participants performed the ASRT task (J. H. Howard, Jr. & Howard, 1997) in which each trial began with four empty circles displayed horizontally 1.2 in., apart across an 8 × 6 in. window on a computer screen, mapped to a keyboard key (the adjoining keys Z, X and symbol keys . and /). Stimulus presentation and response collection occurred via E-Prime with instructions to push the key that matched the filled-in circle’s location. The mapping between the four circles on the screen and middle and index fingers used to respond was parallel for the right and left hands. Thus, the circle on the far left corresponded to the Z key, and the circle second from the left corresponded to the X key, and so forth. On each trial, participants responded to one of four locations that filled in by pressing the key corresponding to the location of the target. The circle remained filled until participants pressed the correct key, at which time it disappeared and a new trial was initiated. The circles remained empty for 120 ms between trials. By giving feedback at the end of each block to focus more on accuracy or on speed, subjects were guided to 92% overall accuracy.

Participants were read instructions prior to beginning the ASRT task on the first session. They were not informed of the presence of any regularities embedded in the task, but were told instead that this was a study about how practice affects motor performance. They were told to respond as quickly as possible to each stimulus presentation and to follow the computer’s instructions to guide their responses for speed and accuracy. At the end of each block, if the percent correct for the last completed block was less than 90%, the computer instructed the participant to “focus more on accuracy.” If the accuracy was greater than 92%, the computer instruction was to “focus more on speed.”

All participants completed three sessions of the ASRT in a single lab visit, with each session taking ~ 20 min and followed by at least a 5-minute break. In each session, there were
three epochs, with five blocks in each epoch. Each block began with 8 random trials (for warmup) and was followed by 80 experimental trials. Participants experienced 1200 trials per session, for a total of 3600 trials across three sessions.

For all blocks, the sequence of stimulus locations conformed to an eight-item sequence in which the stimuli followed a predictable four-element-long sequence alternating with randomly determined stimuli. This eight-item sequence repeated 10 times in a block. Participants were randomly assigned one of six possible sequences (1r2r3r4r, 1r2r4r3r, 1r3r42r, 1r3r2r4r, 1r4r3r2r, or 1r4r2r3r, where 1 denotes the position on the far left on the computer screen, 4 denotes the circle on the far right, and r denotes a random element, which was constrained so that any one of the four positions appeared with equal probability). Thus stimuli followed a second-order pattern structure (i.e. sequences of three events which denoted a “triplet”).

The structure of the task causes certain triplets of trials to occur at a higher frequency than others. For instance, for the pattern 1r2r3r4r, sequences such as 1r2, 2r3, 3r4, and 4r1 have a high probability of occurring because they are the only triplets that can occur when the third item is from the pattern as well as when it is random (High-frequency triplets). In contrast, sequences such as 2r1 or 3r2 have a low probability of occurring since they only occur when the third item is random (Low-frequency triplets).

In the ASRT used in the present experiment, the measure of learning is the accuracy and response time difference between predictable and unpredictable events. In particular, accuracy and response times to the last event on High-frequency triplets are compared to that on the last event on Low-frequency triplets. Faster and/or more accurate responding on High- than Low-frequency events with practice is taken as evidence of implicit sequence learning. The larger this trial-type effect, the greater evidence there is of sequence learning.
Tests of explicit awareness of the ASRT sequence. Both Goal and Control groups received the following tests of explicit knowledge. First, at the end of ASRT testing, participants were given a card sorting task (Japikse, Howard, & Howard, 2001). For this task, participants were given a stack of 64 index cards, each of which contained three rows of four circles. One circle on each row was filled with a black color. Each line represented one trial, so each card denoted three consecutive trials on the ASRT task (a triplet). Participants were told to sort each card into one of two piles labeled “Occurred More Often” and “Occurred Less Often” based on how often they thought these triplets of trials occurred on the ASRT. (Appendix G)

Next, a post-experimental interview in which the experimenter read aloud six questions probing for declarative knowledge of the presence of regularities and nature of the pattern was conducted (Appendix H; Japikse, Negash, Howard, & Howard, 2003). These questions were read one at a time, and the experimenter recorded the participant’s responses. Specifically, participants were asked if they had used any strategy to try to improve their performance, and, if so, they were asked to describe the strategy and to evaluate how well that strategy worked. The following questions were asked: (1) Do you have anything to report regarding the task that you did on the computer? (2) Did you notice anything special about the task or the material? (3) Did you notice any regularity in the way the stimulus was moving across the screen? (4) Did you attempt to take advantage of the regularities you noticed in order to anticipate subsequent targets? If so, did this help? (5) In fact, there was some regularity to the sequences you observed. What do you think it was? That is, try to describe any regularity you think might have been there. People who answered “yes” to the second or third questions were encouraged to describe what they had noticed before the experimenter moved on to the next question. The fourth question was posed only if the participant answered “yes” to question 3.
Then, participants were given a *sequence generation* task in which they were asked to produce a typical 16-unit-long pattern that they thought had occurred during each session on the ASRT. They did so by reporting a typical sequence in numbers (1, 2, 3, or 4) to the experimenter, who wrote it down into 16 blank spaces on the piece of paper.

**Tests of explicit achievement motivation.** The awareness probes described in this section replicated the procedure of Eitam et al. (2008). Participants were given a *questionnaire* that asked increasingly specific questions regarding their explicit achievement motivation (Appendix I). Three of these items assessed their explicit motivation to perform the ASRT task. First, they were asked to rate how important it was for them to respond quickly on the ASRT. Second, they were asked to rate how important it was for them to respond accurately on the ASRT. A third item asked participants how important it was for them to succeed on the ASRT. A fourth item assessed participants’ intention to learn the sequence, by asking how important it was for them to “learn the rule by which the stimulus location was determined.” All ratings were made on a 4-point scale ranging from 1 (*not at all important*) to 4 (*very important*).

In addition, participants answered three items measuring their awareness of the goal priming procedure (Eitam et al., 2008). First, they were asked to speculate, in their own words, on the “purpose of the word-search task” (which served as the priming manipulation for the Goal group). Next, they were asked “whether there was anything noteworthy in the word-search task,” and last, they were asked directly whether the word-search task had affected their performance on the ASRT task in any way.

**Memory for WS task words.** The experiment concluded with an item on the explicit achievement motivation questionnaire which assessed participants’ ability to recall “as many words from the word-search list” as they could remember by writing them down in the blank
space that was provided on the paper. This item, which was not used by Eitam et al. (2008), was added to assess explicit memory for the words from the WS task.

**Results**

**Alternating Serial Reaction Time (ASRT) Task**

In the ASRT analysis, implicit learning is measured by increasing differences in reaction time and accuracy between High versus Low triplet sequences with practice. Data from the first 8 random trials of each block were discarded. In addition, responses to High- and Low-frequency triplets were compared only after repetitions and trills had been removed. Howard and colleagues (2004) have shown that people have pre-existing response tendencies for these two triplet types. For instance, they reported that people respond quickly to repetitions which contain three successive identical events (e.g. 111) and relatively slowly on trills which are triplets that begin and end with the same element with a different intervening element (e.g. 121). Therefore, it is assumed that such tendencies may reflect response biases rather than sequence specific learning.

This study tested the hypothesis that participants primed with the goal of achievement show enhanced implicit sequence learning compared to controls by comparing accuracy and reaction time on predictable and unpredictable trials on each block for each person. These means were averaged across successive blocks to obtain a value on each of 9 five-block (400-trial) Epochs for each individual and Trial Type. An alpha level of .05 was used for all statistical tests.

**Reaction time measures.** The median reaction times (for correct trials) on High- and Low-frequency triplets were obtained for each person for each epoch. The means of these median reaction times across epochs for High- and Low-frequency triplets are shown in Figure 1, and reflect data averaged across participants.
A mixed design Group (Goal vs. Control) × Epoch (1-9) × Trial Type (High vs. Low) analysis of variance (ANOVA) with repeated measures on Trial Type and Epoch factors was performed for mean of median reaction times. This ANOVA revealed significant main effects for Epoch \( F(8, 176) = 57.996, MSE = 17702.654, p < .0001 \), indicating that people got faster with practice, and Trial Type \( F(1,22) = 87.748, MSE = 15338.381, p < .0001 \), showing that people were responding to High-frequency triplets faster than Low-frequency ones. There was also a significant Trial Type × Epoch interaction for response times \( F(8,176) = 5.18, MSE = 248.735, p < .0001 \), indicating that this overall trial-type effect (High vs. Low difference) increased with practice and that sequence learning had occurred.

Figure 1 shows that reaction time to High- versus Low-frequency trials diverged with practice for both groups. Over epochs, response times declined more for predictable than for unpredictable trials for both conditions. There was no main effect of Group, indicating that the Goal and Control participants did not differ in overall reaction time. Most importantly, there was also no significant Trial Type × Group or Trial Type × Epoch × Group interaction, indicating that learning was systematic and similar for both groups.

**Accuracy measures.** A similar analysis as above was conducted for accuracy data. Figure 2 shows the plot of the proportion correct responses for High- and Low-frequency triplets for both groups. A mixed design Group (Goal vs. Control) × Epoch (1-9) × Trial Type (High vs. Low) ANOVA of accuracy revealed significant main effects of Epoch \( F(8,176) = 5.716, MSE = .007, p < .0001 \) as accuracy decreased over time. Figure 2 indicates that this effect was due to declining accuracy for Low-frequency triplets, while High-frequency triplets remained relatively stable. This effect was consistent with a significant main effect of Trial Type \( F(1, 22) = 90.708, MSE = .195, p < .0001 \) as well as an Epoch × Trial Type interaction \( F(8,176) = 3.999, MSE = .208 \).
= .003, \ p = .0002). There were no main effects or interactions with Group that approached significance. Thus, the data on both performance measures of reaction time and accuracy showed that participants demonstrated learning of the sequence regularities with practice but that both groups were similarly sensitive to the regularities in the sequence.

These results failed to replicate Eitam et al.’s (2008) findings even though the same goal motivation procedures they employed were used in this experiment. Their study of NCGP demonstrated that priming an achievement goal via a word search task enhanced learning on an SRT task for primed participants compared to participants in the control group.

**Trial-type effects on reaction time and accuracy.** Although the Group × Trial Type interaction was not significant for either accuracy or reaction time, the trial-type effects were plotted to compare the patterns of learning for the two groups more directly (Figure 3). Difference scores for reaction time (i.e., RT on Low-frequency trials minus RT on High-frequency trials) and accuracy (i.e., proportion correct on High-frequency trials minus Low-frequency trials) were calculated for each participant for each of the 9 epochs. These difference scores reflected the extent to which performance on High-frequency trials was exceeded that of Low-frequency trials. Thus, for both measures, sequence specific knowledge was demonstrated by difference scores significantly above zero.

The reaction time difference score data shown in Figure 3 suggest that participants in the Goal group showed more learning than the Control group only in Epoch 3. Accordingly, there was a significant difference between the groups on unpaired \( t \)-tests comparing trial-type effects on the reaction time measures from Epoch 3, \( t(22) = -2.403, \ p = .025 \). Therefore, the results indicate that only in Epoch 3, the goal priming procedure may be increasing the magnitude of the triplet type effect. However, Goal and Control groups did not differ significantly in the
magnitude of the triplet type effect for accuracy in any epoch, which suggests that the goal priming procedure was not influencing this measure.

**Explicit awareness measures for the ASRT.** Responses on the post-experimental interview and generation task showed that participants were not able to explicitly describe the regularity in the ASRT, and revealed no apparent differences between the two groups. Consistent with earlier work with the ASRT task, no one had reported that they found a pattern or were able to describe the regularities they had been exposed to in the trials. In particular, none of the participants identified the alternating structure of the sequence.

Additionally, the card sorting task given at the end of the session revealed that people were unable to judge explicitly the relative frequency with which High-frequency and Low-frequency triplets occurred (Figure 4). In the analysis of the card sorting data, the mean proportion of times participants sorted High-frequency and Low-frequency triplets into the “Occurred More Often” category was calculated. The card sorting data are shown in Table 1. A two-way (Group × Triplet Type) ANOVA carried out on these data revealed a significant main effect for Triplet Type \((F(3,66) = 3.397, MSE = .157, p = .0228)\), which was caused by the significant tendency for people to rate trills as occurring less often than any other triplet type. For example, participants from both groups rated Trills as occurring significantly less often than High-frequency triplets (Goal: \(t(24) = 2.178, p = .0395\); Control: \(t(20) = 2.516, p = .0205\)) and Low-frequency triplets (Goal: \(t(24) = 2.366, p = .0264\); Control \(t(20) = 3.150, p = .0050\)). As suggested by Howard et al. (2004), this could reveal a pre-existing bias or learning of trills. However, these results do not affect the interpretation of the implicit learning measure since there were no significant differences in the rating of High- and Low-frequency triplets from each
other on the recognition measure, and trills and reps were excluded from the ASRT analyses.

**Word search (WS) task**

Each participant was timed on how long it took for them to complete the word search puzzle from start to finish, and each was asked to rate the difficulty of the task on a 4-point scale (ranging from 1 = Easy to 4 = Difficult). On average, participants from the Goal and Control groups took 185 seconds ($SD = 77.6$) and 293 seconds ($SD = 95.2$), respectively, to complete the task. There was no significant difference between groups on an unpaired $t$-test comparing time taken to complete the WS task ($t(22) = -1.22, p = .234$). Out of 4, participants in the Goal group also rated the task difficulty 1.54 ($SD = .52$) compared to 1.82 ($SD = .60$) for Control participants. An unpaired $t$-test comparing difficulty ratings revealed significant differences between the groups ($t(22) = -3.04, p = .006$). These results suggest that the Control group found the WS task significantly more difficult to complete compared to the Goal group.

**Explicit achievement motivation measures.** Responses on the explicit achievement motivation questionnaire were examined for evidence of declarative knowledge of the goal-priming manipulation. Most people did not describe having any explicit awareness of the purpose of the goal-priming word-search task, except for four participants who reported that they noticed achievement-related words embedded in the list. Importantly, no participant reported that the word-search task had affected their performance in any way.

The results for the ratings of explicit achievement motivation replicated the patterns in the study conducted by Eitam et al. (2008). As shown in Figure 5, goal priming did not induce significant changes in explicit motivation to perform the ASRT quickly ($t(22) = -.230$), or accurately ($t(22) = -.278$), or to succeed in the task ($t(22) = -.475$), or intention to learn the rule embedded in the sequence regularity ($t(22) = -1.54$). Thus, the data shows that priming the goal
of achievement using the WS task did not increase participant’s explicit motivation to perform on the ASRT task.

**Words recalled from WS Task.** From the list of words that each participant wrote down at the end of the experiment, only correct words were analyzed. Figure 6 shows the average number of words recalled by each group, i.e., ‘correct’ words. These words were categorized by word types, i.e. ‘common’ or ‘different’ words. Thus, of the 13 target words given to each group, each participant could recall a maximum of 6 common words and 7 different (e.g. achievement-related or motivationally neutral) words. An unpaired t-test for average words recalled revealed no significant differences between the Goal and Control groups for the total number of correct words ($t(22) = -0.438$), or common (correct) words ($t(22) = 0.811$), or different (correct) words ($t(22) = 0.616$). Therefore, the data suggests that people did not remember more achievement-related words than motivationally neutral ones.

**Discussion**

The present experiment aimed to replicate the findings of Eitam et al. (2008) who concluded that implicit learning is enhanced by priming achievement goals. The present study went beyond their design by using a task in which explicit knowledge was eliminated. Despite using the same goal motivation procedure, our results did not support their findings. Overall, the mixed design ANOVAs for both performance measures reveal that both groups show sequence learning with practice. Participants in both conditions demonstrated systematic and similar skill learning on the ASRT, with faster (RT: Trial Type × Epoch, $p < .0001$) and more accurate (Trial Type × Epoch, $p = .0002$) responding over time on High-frequency than Low-frequency trials. But contrary to Eitam et al. (2008), there was no significant difference in overall sequence learning between the groups, in that no Group × Trial Type or Group × Epoch × Trial Type
interactions approached significance. Learning is shown to be purely implicit in this experiment since results on the ASRT card sorting task revealed that participants did not acquire any conscious, explicit knowledge of the underlying pattern that they were assigned. Further, participants could not describe the regularity of the alternating sequence either by verbal report or in a 16-target sequence generation task. These results support the conclusion that implicit sequence learning was not enhanced by priming the goal of achievement.

When the data were examined in more detail, participants in the Goal condition did show significantly more learning in Epoch 3 compared to those in the Control condition for the reaction time measure. This significant difference in learning at the end of the first session (~ 20 minutes after the goal priming procedure) hints at the possibility of a goal motivation effect. Given that this Group effect was only demonstrated in Epoch 3 (only for the reaction time measure) and that there were no significant triple interactions for the ASRT data analysis, these results cannot be clearly attributed to the goal priming manipulation, and warrant additional replication. Our analyses suggest that even if the goal motivation effect is real, it is transient and relatively short-lived. The most curious feature of this effect is that it appears after an extended time lag and disappears within the same epoch. At this time, it is unclear what could have prompted this sudden surge and rapid decay of “goal motivation” specifically in Epoch 3. A preliminary analysis of the data on the individual level revealed that all subjects appeared to be learning systematically. Also, the individual learning curves showed that a majority of subjects in the Goal group, but not in the Control group, displayed an increase in the magnitude of the triplet type effect for the reaction time measure in Epoch 3. A next step in data analysis includes conducting a block analysis for the first four epochs so as to examine this phenomenon more thoroughly. Furthermore, given that the apparent effect was seen early on in the ASRT task,
future studies may replicate the same procedures but focus on examining learning specifically in
the first two sessions (i.e., Epochs 1-6).

One possible explanation for the discrepancy between the present results and Eitam et
al.’s (2008) is that perhaps goal motivation only influences explicit learning. Participants in the
prior study showed evidence of some explicit knowledge of the underlying SRT sequence
structure. In the present study, explicit knowledge was completely ruled out using more sensitive
recognition techniques. Alternatively, differences in our findings might be explained by the idea
that the effects of goal motivation only influences very early implicit sequence learning and/or
the learning of simple deterministic sequences. Eitam et al. (2008) examined the RT difference
between a fixed-sequence block and two random adjacent blocks in the SRT in which each block
was only 50 trials long. By contrast, the present study examined the course of sequence learning
in the ASRT based on trial-type effects over 3600 trials. Thus, their study of implicit learning
was limited to a much earlier period of learning compared to the extended course of learning that
was examined in the present study.

The results of the explicit motivation assessments replicated Eitam et al.’s (Experiment 2;
2008) findings that goal priming failed to induce significant alterations in a person’s intention to
excel on the sequence learning task. However, it is uncertain if the word search goal-priming
procedure invented by Bargh et al. (2001) was effective at priming the goal of achievement in
the participants in the first place. In follow-up studies, it would be valuable to examine the
effectiveness of the goal-motivation priming procedure by, for example, giving participants a
word-stem completion task or a lexical decision task as an indirect test of priming, to assess if
goal-primed participants have a preference to respond to achievement-related words.
Moreover, since Eitam et al. (2008) conducted their study at Hebrew University in Jerusalem, the actual materials used in their study were in Hebrew rather than English language. The primary author was contacted to confirm this fact. The researchers reported that the 7 words associated with achievement were: ambitious, aspiration, competition, excellence, first, race, and win and the words used to replace them in the control condition were: carpet, diamond, farm, hat, topaz, and window. Although the goal-priming words embedded in the word search puzzles for their study used words that were modeled on the concept of achievement, they may have had specific cultural salience to the group of participants or even different meanings when translated into the foreign language. For example, to an average American college student, the words that were used in the control condition, such as diamond or topaz or farm might connote rare treasures or wealth or rural society, respectively. Such an interpretation might trigger nonconscious goal pursuit. Therefore, it is possible that the inconsistency in the material used for the WS task may have resulted in non-equivalent findings in this study.

In conclusion, although the results of the current study did not support Eitam et al.’s (2008) findings that goal motivation enhances implicit learning, they provide intriguing evidence for further examining this claim. Following the recommendations stated above, future experiments should examine the timing of any such effect and further investigate the role of goal motivation in mechanisms underlying implicit learning.
References


### Tables

Table 1

*Mean Proportion “more often” category, ASRT (standard deviations)*

<table>
<thead>
<tr>
<th>Group</th>
<th>High frequency</th>
<th>Low frequency</th>
<th>Trills</th>
<th>Repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>.59 (.11)</td>
<td>.62 (.08)</td>
<td>.44 (.17)</td>
<td>.64 (.42)</td>
</tr>
<tr>
<td>Goal</td>
<td>.60 (.13)</td>
<td>.59 (.07)</td>
<td>.47 (.18)</td>
<td>.63 (.28)</td>
</tr>
</tbody>
</table>
**Figure 1.** Mean of median reaction times (RTs in milliseconds) as a function of epoch and trial type for both groups on the serial reaction time task. The red graph represents mean performance on High- (filled-in circles) and Low-frequency (open circles) trials for the Goal group, and the blue graph represents mean performance on High- (filled-in circles) and Low-frequency (open circles) trials for the Control group. Error bars indicated here denote ± 1 standard error.
Figure 2. Mean accuracy (proportion correct) on high and low probability trials as a function of epoch and trial type for both groups on the serial reaction time task. The red graph represents mean performance on High- (filled-in circles) and Low-frequency (open circles) trials for the Goal group, and the blue graph represents mean performance on High- (filled-in circles) and Low-frequency (open circles) trials for the Control group. Error bars indicated here denote ± 1 standard error.
Figure 3. Trial type effect (the difference between performances on High- and Low-frequency trials) split by epoch (1-9). The top graph shows the difference scores for the response time measure (in milliseconds). The bottom graph shows the difference score for the accuracy measure (in terms of differences in proportion correct between the two trial types). The red and blue graphs represent performance measures for the Goal and Control groups, respectively. Based on the reaction time difference score, the goal condition showed significantly more learning than the goal condition only on Epoch 3. Error bars indicated here denote ± 1 standard error.
Figure 4. Mean proportion of cards sorted in the “Occurred More Often” category as a function of triplet type (High-frequency, Low-frequency, Trills, or Repetitions). The red and blue graphs represent performance measures for the Goal and Control groups, respectively. Error bars indicated here denote ± 1 standard error.
Figure 5. Analysis of explicit achievement motivation in the goal-priming group (red graph) and control group (blue graph) to perform the ASRT task quickly (i.e., fast), or accurately, or to generally succeed, or to learn the regularities in the sequence (i.e. learn rule) based on a 4-point rating scale. A rating of 1 corresponded to “not at all important” and a rating of 4 corresponded to “very important”. Error bars indicated here denote ± 1 standard error.
Figure 6. Number of correct words recalled by participants as a function of word type (Common or Different) and group. Based on the 13 target words in the word search task, a maximum of 6 common words and 7 different (i.e. achievement-related or motivationally neutral) words could be recalled for each group. The red and blue graphs represent data for the Goal and Control groups, respectively. Error bars indicated here denote ± 1 standard error.
Appendix A

Goal-Primming Word Search Task

S U E H P E J G A E
P T H V L N U R T T
H M R P E K W E T E
B Z A I B I A E A P
L T L L V A H N I M
S U C C E E D C N O
G N I D L I U B A C
R E T S A M I N K L
W T U R T L E I N W
T N A L P A H W B X

Target Words:

ACHIEVE
ATTAIN
BUILDING
COMPETE
GREEN
LAMP
MASTER
PLANT
STAPLE
STRIVE
SUCCEED
TURTLE
WIN
Appendix B

Completed Goal-Priming Word Search Puzzle

![Completed Goal-Priming Word Search Puzzle Diagram]

Diagram of completed word search task for the Goal group, with achievement-related words circled in blue ink.
Appendix C

Control Condition Word Search Task

Target Words:

BUILDING
CARPET
GREEN
HAT
LAMP
PLANT
RANCH
RIVER
ROBIN
SHAMPOO
STAPLE
TURTLE
WINDOW
Completed Control Condition Word Search Task

Diagram of completed word search task for the Control group, with motivationally-neutral words circled in blue ink.
Appendix E

**Instructions for ASRT task**

In this study, we are trying to learn more about how practice affects motor performance. We want to find out just how much people are able to speed up their responses when they are given extended practice on a reaction time task.

There will be three sessions of the following task. The computer screen will display a horizontal row of four open circles, as shown below:

![Four open circles](image)

A “target” will occur in one of these four locations. The target will consist of one of the circles filling in with a black color, as shown below.

![Four open circles with one black](image)

You should respond by pressing the key which corresponds to the location of the target as quickly as possible. To do this, please place your left middle finger, left index finger, right index finger, and right middle finger on the keys marked with yellow, and keep your fingers positioned in this way throughout the block of trials. As soon as a circle fills in with a black color, press the corresponding key beneath it.

If you respond correctly, this will cause that circle to become open again and another target will appear. You should then press the key corresponding to the new target as quickly as possible. When you press the wrong key, the circle will remain unchanged until you press the correct key.

At the end of each block, the computer will display your response time and accuracy for the most recent block. The computer will guide you by asking you to focus more on accuracy or on speed. Please follow these instructions. Your main goal is to try to get faster and faster over blocks, while maintaining acceptable accuracy, and see if you can continue to improve throughout the session.
Scheme of implicit sequence learning in the alternating serial reaction time (ASRT) task denoting the pattern 1r2r3r4r, in which the red boxes represent predictable pattern events alternating with unpredictable random events for 8 consecutive trials.
Appendix G

Instructions for ASRT Card Sorting Task

I have given you a stack of cards, each of which has three rows of four circles on it. Each line of four circles represents one trial that you saw on the screen. You will see that one of the circles has been filled in on each line, giving you three sequential trials with their corresponding targets. So, for example, if I showed you a card with the following:

This would represent a series in which three successive filled in circles consisted of (1) pushing your left middle finger, (2) pushing your left index finger, and then (3) pushing your left index finger.

Your job is to place each card into one of two piles depending on how often you think the series occurred during the three test sessions. The piles are labeled, “Occurred More Often” and “Occurred Less Often”. Please use these categories to sort the cards.

Do you have any questions?
Appendix H

Interview: Explicit Knowledge of ASRT Sequence

Subject ______
Date: Time: 
Experimenter: JL

Post-Experimental Interview

Read these questions one at a time and record the participant’s responses:

1. Do you have anything to report regarding the task?

2. Did you notice anything special about the task or the material? (If “yes,” please describe.)

3. Did you notice any regularity in the way the stimulus was moving on the screen? (If “yes,” please describe the sequence in your own words. Then, ask question 4. If “no,” skip to question 5.)

4. Did you attempt to take advantage of the regularities you noticed in order to anticipate subsequent targets? If so, did this help?

5. In fact, there was some regularity to the sequences you observed. What do you think it was? That is, try to describe any regularity you think might have been there.

6. Please describe in words or show me with your fingers, a typical sequence of 16 targets.
Appendix I

**Questionnaire: Explicit Achievement Motivation & Memory for WS Words**

Subject ______
Date: ________ Time: ________
Experimenter: JL

**Post-Experimental Questionnaire**

1. How important it was for you to respond quickly on the dots task?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all Important</td>
<td>Somewhat not Important</td>
<td>Somewhat Important</td>
<td>Very important</td>
</tr>
</tbody>
</table>

2. How important was it for you to respond accurately on the dots task?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all Important</td>
<td>Somewhat not Important</td>
<td>Somewhat Important</td>
<td>Very important</td>
</tr>
</tbody>
</table>

3. How important was it for you succeed in the dots task?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all Important</td>
<td>Somewhat not Important</td>
<td>Somewhat Important</td>
<td>Very important</td>
</tr>
</tbody>
</table>

4. How important was it for you to learn the rule by which the stimulus location was determined?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all Important</td>
<td>Somewhat not Important</td>
<td>Somewhat Important</td>
<td>Very important</td>
</tr>
</tbody>
</table>
5. What was the purpose of the word-search task?

6. Was there anything noteworthy in the word-search task?

7. Did the word-search task affect your performance on the dots task in any way?

8. Please write down as many words from the word-search list as you can remember.
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