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Effects of priming goal pursuit on implicit sequence learning

Katherine R. Gamble,

Department of Psychology, Georgetown University, 3700 O St. NW, 306 White Gravenor Hall, Washington, DC 20057, p: 202-687-4099, f: 202-687-4042

Joanna M. Lee,

Department of Psychology, Georgetown University, 3700 O St. NW, 306 White Gravenor Hall, Washington, DC 20057

James H. Howard Jr., and

¹Department of Psychology, The Catholic University of America; ²Department of Psychology, Georgetown University; ³Department of Neurology, Georgetown University Medical Center, 620 Michigan Ave. NE, 308 O'Boyle, Washington, DC 20064

Darlene V. Howard

Department of Psychology, Georgetown University, 3700 O St. NW, 306 White Gravenor Hall, Washington, DC 20057

Katherine R. Gamble: krg27@goergetown.edu

Abstract

Implicit learning, the type of learning that occurs without intent to learn or awareness of what has been learned, has been thought to be insensitive to the effects of priming, but recent studies suggest this is not the case. One study found that learning in the Serial Reaction Time (SRT) task was improved by nonconscious goal pursuit, primed via a word search task (Eitam et al., 2008). In two studies, we used the goal priming word search task from Eitam et al., but with a different version of the SRT, the Alternating Serial Reaction Time task (ASRT). Unlike the SRT, which often results in explicit knowledge and assesses sequence learning at one point in time, the ASRT has been shown to be implicit through sensitive measures of judgment, and it enables sequence learning to be measured continuously. In both studies, we found that implicit learning was superior in the groups that were primed for goal achievement compared to control groups, but the effect was transient. We discuss possible reasons for the observed time course of the positive effects of goal priming, as well as some future areas of investigation to better understand the mechanisms that underlie this effect, which could lead to methods to prolong the positive effects.

Keywords

nonconscious; goal pursuit; implicit learning; priming; sequence learning; implicit sequence learning

Conflict of Interest

The authors declare that they have no conflict of interest.

Introduction

Our behavior can be manipulated by external cues, or primes, without our awareness. For example, we may be more tidy when smelling a citrus scent (Holland et al. 2005), or walk more slowly after being primed with stereotypical words related to aging (Bargh et al. 1996). Primes can even activate a goal without awareness, priming people to seek success and reach an end goal (Bargh et al. 2001).

Most research investigating such priming has examined its effects on declarative learning and memory, or other explicit behaviors (Dijksterhuis et al. 2000; McCulloch et al. 2008; Hassin et al. 2009). In the past, implicit learning, which can occur without intent to learn or knowledge of what has been learned (Reber 1989), was thought to be unaffected by primes, due to its automatic and habitual nature (Cleeremans et al. 1998). Recently, however, some studies have suggested that implicit processes actually *can* be affected by priming, such as priming of negative affect (Shang et al. 2013), mindset (Wulf et al. 2012), or motivational goal pursuit (Eitam et al. 2008).

In Eitam et al. (2008), goal pursuit was primed through a widely used word search puzzle, where 13 words were embedded in a 10×10 letter matrix (Bargh et al. 2001; Hassin et al. 2009). Participants in the goal motivation group searched for seven goal-related words (e.g., achieve) and six motivation-neutral words (e.g., carpet), while those in the control group searched for 13 motivation-neutral words. To investigate how nonconscious goal pursuit affected implicit sequence learning, Eitam et al. (Experiment 2) used the Serial Reaction Time task (SRT; Nissen and Bullemer 1987). In the SRT, participants responded as quickly as possible to the spatial location of stimuli appearing in one of four locations in the center of the computer screen. During training, participants encountered a ten-item sequence of locations that repeated 20 times, and were then given three test blocks, consisting of two blocks of random trials with a block of patterned trials in between. Implicit sequence learning was measured as the difference in reaction time between the patterned and random test blocks. Eitam and colleagues found that the goal group showed more sequence learning than the control group.

This study is important in being the first to show that priming of goal pursuit improved learning on an implicit learning task, but there are limitations regarding both the implicitness of the SRT and the measurement of learning at only one time point. In the SRT (Nissen and Bullemer 1987), participants frequently become aware of the pattern being learned due to the deterministic and repeating nature of the pattern. Eitam et al. (2008) did report that their priming and control groups did not differ on the measures of explicit knowledge they used, but their measures did not make it possible to determine whether or not this knowledge was greater than what would be expected by chance. Therefore, participants in Eitam et al. may have had some explicit knowledge of the pattern that was learned, making it difficult to know whether their findings are showing effects of goal motivation on *implicit* learning. Additionally, participants completed four training blocks before sequence learning was tested, so any effects of goal motivation on earlier (or later) training could not be assessed.

In the present two studies, we use the same word search technique as Eitam et al. (2008) to induce goal motivation, but a different implicit sequence learning task, the Alternating Serial Reaction Time (ASRT; Howard Jr. and Howard 1997) task. The ASRT has been shown to provide a relatively pure assessment of implicit learning; sensitive measures indicate that even after extended training, participants cannot distinguish pattern-consistent sequences of events from pattern-inconsistent ones (Howard Jr. et al. 2004). In addition, sequence learning in the ASRT is measured continuously throughout training, allowing us to investigate the time course of goal motivation effects as learning progresses.

Experiment 1

Method

Participants—Participants were 23 Georgetown University students who participated for course credit or monetary compensation. Participants were randomly assigned to either a Goal ($n = 11$, $M_{age} = 20.46$, $SD = 0.69$, 7 females) or a Control group ($n = 12$, $M_{age} = 20.58$, $SD = 1.83$, 9 females). All procedures were approved by the Georgetown University Institutional Review Board.

Tasks

Word Search: Words that were presented in each of the word searches were taken from Bargh et al. (2001). The word search was a pencil and paper test, and consisted of a grid of letters, 10×10 , with 13 words embedded within it (Bargh et al. 2001; Eitam et al. 2008). There were two versions of the word search, one for the Goal group and one for the Control group. Six of the 13 words were found in both versions (building, green, lamp, plant, staple and turtle), while seven goal-related words were exclusive to the Goal group (achieve, attain, compete, master, strive, succeed and win), and seven motivation-neutral words were used only in the Control group (carpet, hat, ranch, river, robin, shampoo and window). Participants were provided with a list of the 13 words they were to find, and were given as much time as they needed to complete the word search.

Alternating Serial Reaction Time (ASRT) task: In the ASRT, a task derived from Nissen and Bullemer's (1987) Serial Reaction Time task (Howard Jr. and Howard 1997), there were four open circles arranged in a row across a computer screen, and these circles filled in black, one at a time. Participants responded to the location of a filled in dot using a corresponding keypress on a keyboard, and each dot remained filled in until the participant made a correct response. There was then a 120 ms interstimulus interval before the next dot filled in. Unbeknownst to participants, the location of the filled in dots followed a 4-element-long pattern. The pattern occurred on alternating events, such that event one adhered to the pattern, event two occurred in a random location, event three again appeared adhering to the pattern, and so on. For example, if the locations of the four circles corresponded to locations 1 to 4 from left to right, one pattern that occurred was 1r2r3r4r, such that the first event occurred in location one, the second event, denoted by r, occurred randomly in one of the four locations, the third event occurred in location two, and so on, according to the pattern. This pattern kept repeating throughout all blocks of the experiment with no demarcation between repetitions, e.g., 1r2r3r4r1r2r3r, and so on. There were six possible patterns that

were counterbalanced across groups and participants: 1r2r3r4r, 1r2r4r3r, 1r3r4r2r, 1r3r2r4r, 1r4r2r3r, and 1r4r3r2r, with each participant encountering only one of these patterns throughout the task.

As a result of this alternating pattern, some three-element sequences (triplets) occurred with a high probability and some with a low probability. For example, if the pattern is 1r2r3r4r, then 1×2 is a High probability triplet, because triplets beginning with 1 and ending with 2 occur every time the pattern is repeated. In contrast, 2×1 is a Low probability triplet, because it does not follow the pattern, only occurring occasionally when 2 and 1 are occurring as random events. Sequence learning was measured as *Triplet type effects*, i.e., response to the third event in High probability compared to Low probability triplets, for both accuracy and response time. Repetition (e.g.: 1-1-1) and Trill (e.g.: 1-2-1) triplets were not included in the analysis, as they occurred with low probability for all participants (unlike all other triplets which were high probability for some participants but low probability for others), and they have been previously shown to have different response tendencies (Howard et al. 2004).

End of block feedback was displayed on the screen so as to direct participants to achieve 92% accuracy; if accuracy was 94% in a given block, the participant was cued to “focus more on speed,” or, if it was 91%, to “focus more on accuracy.” If accuracy was 92 – 93%, participants were told to, “Please continue,” suggesting that they were performing optimally. Each block began with 8 random events, and then 80 patterned trials per block, such that the pattern repeated ten times in one block. In this experiment, there were fifteen blocks in one session of the ASRT. Data were analyzed in epochs of time, consisting of 3 blocks per epoch, for five epochs in the session. Short breaks were allowed between blocks.

Alternating Serial Reaction Time Card Sorting task: A card sorting task probed explicit knowledge of the pattern (Bennett et al. 2007). Participants were given 64 note cards, with each one depicting one of the 64 possible triplets of events that were seen during the ASRT. Each card had three rows of 4 circles, 3 of which were open and 1 filled in on each row, to represent an event. Therefore, a card may have contained the triplet 1-3-2, such that the first row had location 1 filled in, the second row had location 3 filled in, and the last row had location 2 filled. Participants were told to place each card into one of two piles, labeled either, “Occurred More Often,” or “Occurred Less Often,” based on how frequently they thought each triplet occurred during ASRT training.

Procedure

Participants provided informed consent and filled out a biographical and a health screening questionnaire upon arrival at the lab. They were then told that the visit would have two parts. Participants were first given the Word Search task, either the Goal or Control version, depending on the group to which they were assigned. Once they had completed the Word Search, they were read instructions for and completed one session of the ASRT. Following the ASRT, they completed the ASRT Card Sorting task to assess their explicit knowledge of the pattern. Participants in both groups were then asked to recall as many words as they could from the Word Search. Finally, participants were debriefed and either paid or awarded course credit.

Results and Discussion

ASRT accuracy—A 2 (Group: Goal vs. Control) x 2 (Triplet type: High vs. Low) x 5 (Epoch: 1–5) mixed-design ANOVA was run on accuracy, where Group varied between-subjects and Triplet type and Epoch within-subjects. There were significant main effects of Epoch, $F(4,84) = 8.84, p < .001$, such that accuracy decreased over time (Epoch 1: $M = 0.940, SD = 0.042$; Epoch 5: $M = 0.909, SD = 0.041$), likely due to the end of block feedback guiding them toward 92% accuracy, and of Triplet type, $F(1,21) = 37.91, p < .001$, such that people responded more accurately to High ($M = 0.934, SD = 0.022$) than to Low ($M = 0.906, SD = 0.032$) probability triplets. There was also a significant interaction of Triplet type x Epoch, $F(4,84) = 3.19, p = .017$, such that the accuracy to High probability triplets remained high throughout (Epoch 1: $M = 0.945, SD = 0.039$, Epoch 5: $M = 0.925, SD = 0.025$), while accuracy to Low probability triplets decreased with training (Epoch 1: $M = 0.936, SD = 0.045$, Epoch 5: $M = 0.890, SD = 0.042$). Thus, as assessed by accuracy, there was significant sequence learning as seen through the Triplet type effect, which increased with training. Further, there were no main effects or interactions involving Group, $p > .10$, such that the groups did not differ in overall accuracy (Goal, $M = 0.92, SD = 0.02$, Control, $M = 0.92, SD = 0.03, t(21) = -0.39, p > .10$), and learning occurred to a similar degree in both groups.

ASRT mean of median reaction time—A $2 \times 2 \times 5$ mixed-design ANOVA on reaction time yielded significant main effects of Epoch, $F(4,84) = 16.61, p < .001$, and Triplet type, $F(1,21) = 23.26, p < .001$, and a significant interaction of Triplet type x Epoch, $F(4,84) = 43.22, p = .016$. As can be seen in Figure 1, reaction time decreased over epochs, with participants responding faster to High compared to Low probability triplets, and this Triplet type effect increased with time, showing learning of the sequential regularity. The main effect of Group was not significant ($p > .10$), indicating that there was no overall effect of goal priming on speed. Most important, there was a marginal three-way interaction of Group x Triplet type x Epoch, $F(4,84) = 2.21, p = .07$, suggesting that learning differed between groups over time. These Triplet type effects can be seen more clearly in Figure 2, which shows reaction time difference scores (RT to Low minus RT to High probability triplets) over epochs. Post hoc t-tests at each epoch indicated that the Triplet type effect differed marginally between groups only in Epochs 2 and 4, where this effect was larger in the Goal than the Control group in Epoch 2 ($t(21) = -1.93, p = .067$), but larger in the Control group than in the Goal group in Epoch 4 ($t(21) = 1.86, p = .077$). Thus, in keeping with Eitam et al. (2008), we found a trend toward learning differences between the two groups, such that the Goal group showed more learning relatively early in training. However, in this study, the effect was transient, and the two groups actually reversed in Epoch 4, with the Control being superior, and then the group difference disappeared by Epoch 5.

ASRT Card Sorting—Results of the ASRT Card Sorting task are shown in Figure 3. A 2 (Group) x 4 (Triplet type: High, Low, Repetition, Trill) ANOVA on these data revealed a significant main effect of Triplet type, $F(3,63) = 3.19, p = .03$, but no main effect or interactions involving Group ($p > .10$). As can be seen in Figure 3, participants in both groups rated Repetition and Trill triplet types as having occurred less often than High and

Low triplet types. This indicated that participants understood the rating task, as they were correct in rating Repetitions and Trills as not having occurred frequently.

High and Low probability triplets are the only Triplet types included in the implicit sequence learning analyses above, and so it is important that participants did not rate High probability triplets as having occurred more often than Low probability triplets in either the Goal ($t(10) = -0.146, p > .10$) or Control groups ($t(11) = 0.774, p > .10$). Thus, we can conclude that the learning measured by the Triplet type effect in the ASRT was implicit for both groups.

Word Search free recall—For participants in the Goal group, we recorded how many goal-related words and total words they recalled. (For one Goal participant, only the total number of words recalled was recorded.) Participants in the Goal group did not recall more goal-related ($M = 3.10, SD = 1.91$) than motivation-neutral words ($M = 2.20, SD = 1.48; t(9) = 1.30, p > .10$), and the Goal group ($M = 5.30, SD = 2.63$) did not recall a greater total number of words than the Control group ($M = 5.75, SD = 1.91; t(20) = 0.47, p > .10$). This suggests that the goal-related words were not more salient than the motivation-neutral words for the Goal group.

Experiment 2

The results from Experiment 1 support Eitam et al.'s (2008) earlier findings in suggesting that the goal motivation prime improved implicit learning. However, Experiment 1 yielded only a short-lived advantage for the Goal group, and the interaction with Group was only marginal. Therefore, we conducted a second experiment to replicate these findings, and also to allow extended training in the ASRT to better determine the time course of the goal motivation effect. In Experiment 1, training was only one session long, so in Experiment 2, we extended the ASRT to three training sessions.

Method

Participants—Participants were 24 Georgetown University students who participated for course credit or monetary compensation. Participants were randomly assigned to either a Goal ($n = 13, M \text{ age} = 20.1, SD = 1.0, 12 \text{ females}$) or a Control group ($n = 11, M \text{ age} = 20.7, SD = 1.2, 8 \text{ females}$). All procedures were approved by the Georgetown University Institutional Review Board.

Procedure

All tasks and procedures were the same as in Experiment 1, with the exception of extending training to three sessions in the ASRT.

Results and Discussion

ASRT accuracy—A 2 (Group: Goal vs. Control) $\times$ 2 (Triplet type: High vs. Low) $\times$ 15 (Epoch: 1–15) mixed-design ANOVA on accuracy yielded a pattern of results identical to Experiment 1. There were significant main effects of Epoch, $F(14,308) = 4.24, p < .001$, such that accuracy decreased over time (Epoch 1: $M = 0.932, SD = 0.044$; Epoch 15: $M = 0.901, SD = 0.051$), and of Triplet type, $F(1,22) = 94.03, p < .001$, as people responded more

accurately to High ($M = 0.927$, $SD = 0.019$) than to Low ($M = 0.884$, $SD = 0.030$) probability triplets. There was also a significant interaction of Triplet type $\times$ Epoch, $F(14,308) = 2.52$, $p = .002$, such that the accuracy to High probability triplets remained high throughout (Epoch 1: $M = 0.944$, $SD = 0.036$, Epoch 15: $M = 0.931$, $SD = 0.028$), while accuracy to Low probability triplets decreased with time (Epoch 1: $M = 0.919$, $SD = 0.048$, Epoch 15: $M = 0.872$, $SD = 0.053$). There were no main effects or interactions involving Group, $p > .10$. Thus, as in Experiment 1, for accuracy there was significant sequence learning that occurred to a similar degree in both groups, and the groups did not differ in overall accuracy (Goal, $M = 0.92$, $SD = 0.02$, Control, $M = 0.91$, $SD = 0.02$, $t(22) = -1.02$, $p > .10$).

ASRT mean of median reaction time—A $2 \times 2 \times 15$ mixed-design ANOVA on reaction time yielded significant main effects of Triplet type, $F(1,22) = 88.03$, $p < .001$ and Epoch, $F(14,308) = 45.87$, $p < .001$, and a significant interaction of Triplet type $\times$ Epoch, $F(14,308) = 4.50$, $p < .001$. As can be seen in Figure 4, as in Experiment 1, reaction time decreased over time; participants responded faster to High compared to Low probability triplets, and this Triplet type effect increased with time, signaling learning of the sequential regularity. There was no significant main effect of Group ($p > .10$), indicating that there was no overall effect of goal priming on speed.

Most important, there was also a significant three-way interaction of Group $\times$ Triplet type $\times$ Epoch, $F(14,308) = 1.85$, $p = .03$, suggesting that learning differed between groups over time. Triplet type effects can be seen more clearly in Figure 5. Post hoc t -tests indicated that the Triplet type effect (RT to Low probability triplets minus RT to High probability triplets) differed significantly between groups only in Epochs 4 and 6, where this effect was larger in the Goal than the Control group in Epoch 4 ($t(22) = -3.04$, $p = .006$), but larger in the Control group than in the Goal group in Epoch 6 ($t(22) = 2.54$, $p = .02$). Thus, as seen in Experiment 1, the Word Search prime improved learning in the Goal group early and temporarily, and then the advantage for the two groups reversed briefly, after which there were no group differences.

ASRT Card Sorting—Results of the ASRT Card Sorting task are shown in Figure 6. As in Experiment 1, a 2×4 mixed-design ANOVA revealed a significant main effect of Triplet type, $F(3,66) = 3.57$, $p = .02$, but no main effect of or interaction with Group ($p > .10$). As can be seen in Figure 6, this main effect was driven by participants in both groups rating Trills as having occurred less often than the other three triplet types. This indicates that participants understood the rating task, as they were correct in rating Trills as having occurred infrequently. The incorrect rating that Repetitions were frequent has been shown previously (Howard Jr. and Howard 1997), and might be due to the more extended training in this Experiment. Most important, as in Experiment 1, High and Low probability triplets, the only triplet types included in the implicit sequence learning analyses above, did not differ significantly from each other in either the Goal ($t(12) = 0.924$, $p > .10$) or Control groups ($t(10) = -0.763$, $p > .10$). Thus, learning in the ASRT was implicit.

Word Search free recall—As in Study 1, participants in the Goal group did not recall more goal-related ($M = 3.33$, $SD = 0.99$) than motivation-neutral words ($M = 2.58$, $SD =$

1.73; $t(11) = 1.33, p > .10$), and the Goal group ($M = 5.92, SD = 2.02$) did not recall a greater total number of words than the Control group ($M = 5.55, SD = 2.30; t(21) = -0.41, p > .10$).

General Discussion

The present studies aimed to replicate and extend the effect of priming goal motivation on implicit sequence learning reported by Eitam et al. (2008). We used the same word search priming manipulation as Eitam et al., but measured sequence learning via the Alternating Serial Reaction Time task (Howard Jr. and Howard 1997), rather than the SRT. This change enabled us to ensure that learning was implicit, and to assess how any goal motivation effects varied with the amount of training. Findings in both studies are consistent with those of Eitam et al. in showing that priming goal motivation influenced implicit sequence learning and not speed in general, but there are also important differences.

We build on Eitam et al.'s (2008) findings by showing that a motivational priming effect occurs in a learning task in which there is strong evidence that the learning is truly implicit, as participants were unable to distinguish between high and low probability triplets using a sensitive sorting task. Additionally, because the current task enables continuous measurement of sequence learning, we were able to show that this effect emerged during early training, was transient, and appeared to reverse briefly. That is, the Goal groups showed greater learning early (Epoch 2 in Experiment 1 and Epoch 4 in Experiment 2), and the effect reversed briefly (Epochs 4 and 6 in Experiments 1 and 2, respectively), before disappearing altogether for the remaining epochs. This is particularly obvious in Experiment 2. Thus, the present findings add to the literature showing that priming affects implicit forms of learning (Wulf et al. 2012; Shang et al. 2013), but these results also raise a number of questions.

It is not clear why the goal motivation advantage was short-lived, or why it reversed briefly, but there are at least two possible explanations. First, any goal motivation effects might decay with time, and so perhaps the Goal group's advantage was transient because by several epochs into training, the priming effect had dissipated. It is hard to compare the timing of our study with that of Eitam et al. (2008) because the procedures and thus timing were different, but it seems safe to assume, from the timing described by Eitam et al., that they assessed the effects on learning within three minutes, somewhat under the time (approximately 10 minutes) at which we saw the goal advantage in the present studies. We might not have seen the goal advantage until later in our studies because the ASRT contains a more subtle and difficult regularity than the SRT, and thus takes longer for learning to appear, and hence for effects of the goal prime to be measurable. Regardless, while this interpretation assuming dissipation of the priming manipulation may explain the transient nature of the Goal group's learning advantage, it does not explain the reversal seen immediately following the peak of learning in the Goal groups in both studies.

A second possibility is that, as Atkinson and Birch have argued in their "dynamic theory of action" (c.f. Bargh et al., 2001), such goals do not dissipate with time, but rather remain primed only until a person reaches an optimal level of performance, at which time there is an

immediate drop to the lowest level of goal activation. This is supported by Bargh et al. (2001; Experiment 3), who determined that, while goal motivation priming did dissipate during a passive task (impression formation), just as perceptual forms of priming (e.g., aging-related words) dissipate with a delay, goal motivation priming actually *increased* during a delay before a goal-driven word search task. While Bargh et al. did not have a post-test measure of performance after a goal was attained, our findings are consistent with the goal attainment pattern, in that the Goal groups' highest level of sequence learning (as assessed by the Triplet type effect) was immediately followed by a drop in the sequence learning measure before leveling off in both experiments. This goal attainment interpretation, then, may explain the reversal seen in our Goal groups in both studies.

The ASRT differs from the task used by Bargh and colleagues (2001), however, in that our participants were not given an explicit goal to learn the regularity (in fact were not even told the sequential regularity was present), so they would not know when they had met such a goal. Nonetheless, they were given an explicit goal via instructions. Before beginning the ASRT, participants were instructed that their "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." These instructions were then followed by end-of-block feedback, which instructed participants to be faster, to be more accurate, or to continue, if their accuracy levels were optimal. Thus, guided by a goal to be quick and accurate, participants in the Goal group may have been driven to "attain" a goal, achieving it only when end of block feedback continuously indicated that their performance was optimal. Future research is needed to distinguish among these explanations of the transient and reversing nature of the goal motivation effect.

In addition, research needs to address the biological mechanism through which this goal priming affects behavior. One likely route is via the dopamine system (Custers and Aarts 2005; Aarts 2007; Aarts et al. 2007). Dopamine may be involved in the goal primed response through motivation, or the drive to reach a rewarding goal (Aarts 2007), as the dopamine system has been shown to be involved in both direct response to reward (e.g., drug reinforcement) or behavioral associations, such as action that will lead to a desired outcome (Salamone et al. 2005). Thus, if the dopaminergic system was stimulated by goal priming in the present studies, it is reasonable to suggest that this increased dopamine may have, at least temporarily, improved sequence learning. In fact, using a task similar to the ASRT, it has been shown that implicit sequence learning is better in people with a dopamine transporter genotype that is related to more dopamine availability (Simon et al. 2011). Additionally, people who are in advanced stages of Parkinson's disease, and thus who have low levels of dopamine in the area of the brain associated with implicit learning, show impaired sequence learning compared to controls (Wilkinson et al. 2009; Gamble et al. 2014). Future studies, however, will aim to better elucidate the mechanism through which this goal motivation temporarily facilitated implicit learning in the present studies. Having a better understanding of the mechanisms underlying the effects of goal motivation could provide an opportunity to examine ways to prolong these positive effects.

We are unable to determine exactly why the effect of goal motivation is transient and shows a reversal in the present studies. Motivation has been shown to improve trial-to-trial learning

on a motor task (Kühn et al. 2008), and researchers suggested that this effect was related to dopamine release within the basal ganglia (Kempf et al. 2007; Kühn et al. 2008). Thus, if goal motivation caused an increase in dopamine release in the basal ganglia, this would have helped to improve sequence learning, which has a positive relationship with more dopamine availability (Simon et al. 2011). Additionally, motivation has been shown to decrease once a goal is reached, or that motivation is sated (c.f., Heine et al. 2006), which is in line with the dynamic theory of action (c.f., Bargh et al. 2001), mentioned above. We therefore propose that although the effects of goal motivation are short-lived, they are important, and possibly initiated and driven by dopamine and a goal to achieve, which then dissipates once performance reaches an optimal point.

These effects, both improved learning and the possible satiation of motivation upon success, may also be affected by the instructions to be fast and accurate that were given at the beginning of the ASRT, as well as by instructions given with end-of-block feedback. Although neither of these instructions directed participants to implicitly learn a sequence (i.e., the actual goal of interest to us), participants could have been driven to achieve a level of success in order to receive the, “please continue,” end-of-block feedback, which indicated that their performance was optimal. Participants in the present study were also instructed to be as quick and accurate as possible, which may have provided an additional goal to participants, beyond those instructions given to participants in Eitam et al. (2008).

In fact, we cannot be sure that the goal motivation we primed was nonconscious. Unlike Eitam et al. (2008), we did not include questions to probe participants’ explicit motivation to achieve a goal, so we cannot claim that goal motivation was nonconscious. It is of interest that in the post-learning Word Search recall task in the present studies, the Goal group did not remember the goal-related prime words significantly better than the motivation-neutral words by the end of learning. This suggests that goal-related words were not particularly salient to the Goal group, but nonetheless these results do not speak directly to the issue of the consciousness of the goal motivation. Future research should address whether conscious and nonconscious priming have different effects on implicit learning.

A puzzling aspect of our findings is that, although both of the present experiments showed superior sequence learning in the Goal group at some point in training, the time course of this effect differed slightly between the two experiments. One potential reason for different timing is that the time allowed for breaks between blocks was participant-controlled, and thus, it is possible that the amount of time taken by participants differed across studies. However, despite the unexplained variation in the time course of the effect, we suggest that the superior learning seen is a real, if transient, effect of goal motivation priming, because this superiority of learning in a goal motivation group was shown first by Eitam and colleagues (2008) with the SRT, and twice in the present studies with the ASRT. Experiment 2, with its longer training, should be replicated in a larger sample to better understand when, and perhaps how, goal motivation improves implicit learning.

The present studies showed that implicit sequence learning is influenced by priming goal motivation. These findings, along with those of Eitam et al. (2008) are important, as it had previously been thought that implicit learning was impervious to effects of priming. These

findings have implications for other sequencing behavior, such as rehabilitation in injured populations, suggesting that priming can influence, and more importantly, improve, learning of sequences of events.

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Fig. 1.
Mean of median reaction time for Experiment 1. Error bars indicate standard error

Fig. 2.
Mean of median reaction time difference scores (RT for Low probability trials minus RT for high probability trials) for Experiment 1. Error bars indicate standard error

Fig. 3.

Results for the ASRT Card Sorting Task in Experiment 1, showing the proportion of triplets rated as having occurred most often, filed into High, Low, Repetition or Trill triplet types. Error bars are standard errors

Fig. 4.
Mean of median reaction time for Experiment 2. Error bars indicate standard error

Fig. 5. Mean of median reaction time difference scores (RT for Low probability trials minus RT for high probability trials) for Experiment 2. Error bars indicate standard error

Fig. 6. Results for the ASRT Card Sorting Task in Experiment 2, showing the proportion of triplets rated as having occurred most often, filed into High, Low, Repetition or Trill triplet types. Error bars are standard errors