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RESEARCH REPORT

Motivation to Avoid Loss Improves Implicit Skill Performance

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Implicit learning reflects learning from experience that occurs without intention or awareness of the information acquired and is hypothesized to contribute to skill acquisition by improving performance with practice. The role of motivation has not been examined because this kind of memory is represented outside awareness. We manipulated motivation (approach/avoidance) and type of feedback (positive/negative) to measure how these affected a well-studied task of implicit sequence learning. Across 2 experiments, we found a consistent effect that motivation to avoid loss led to much higher levels of sequence-specific task performance. When the motivation manipulation was removed, performance fell to typical levels, indicating that motivation enhanced knowledge expression through performance, not learning. Even though implicit skill knowledge is represented outside awareness, our ability to apply this knowledge is enhanced when motivated by fear of loss, potentially providing insight into the value of coaching/training practices that motivate performers in this manner.

Keywords: implicit memory, motivation, learning

A stereotype common in sports, music, and other skilled performance contexts is that of the tough coach, who is extremely challenging, using negative comments or even threats as motivation. A possible rationale for this motivational style is that this approach produces better skill acquisition or performance. To test this hypothesis, we examined effects of motivational state on a laboratory task that isolates memory critical to skilled performance. The Serial Interception Sequence Learning (SISL) task measures implicit skill learning (Sanchez, Gobel, & Reber, 2010; Sanchez & Reber, 2013; Thompson, Sanchez, Wesley, & Reber, 2014) and operates almost entirely independently from explicit knowledge (Sanchez & Reber, 2013), producing robust learning without conscious knowledge. The effect of motivation on implicit learning was assessed using a well-studied manipulation of motivational state toward approach or avoidance (e.g., Higgins, 1997; Shah, Higgins, & Friedman, 1998).

The SISL task is a measure of motor sequence learning that has the unique property that explicitly instructing participants on the underlying repeating sequence does not lead to faster learning or better performance (Sanchez & Reber, 2013). Because of this feature, even the modest amounts of explicit recognition sometimes obtained by cognitively healthy participants performing the task (e.g., Sanchez, Gobel, & Reber, 2010) do not appear to influence task performance. As a result, effects of manipulations of motivational state on SISL will indicate how motivation affects implicit skill learning separately from other potential effects on explicit learning and memory.

Historically, implicit learning had been thought to operate automatically and to be immune to manipulations of mental state, such as a secondary task (cf., Schumacher & Schwarb, 2009; Nemeth et al., 2011). However, more recent results have suggested that implicit learning can be affected by mood manipulations (Shang, Fu, Dience, Shao, & Fu, 2013; Bertels, Demoulin, Franco, & Destrebecqz, 2013). Thompson et al. (2014) showed that ego depletion, or the notion that central executive functions can be weakened through depletion of cognitive control resources (Baumeister, Vohs, & Tice, 2007), can negatively impact implicit learning as well. Taken together, these results suggest that current mental/emotional sates can have significant effects on implicit learning.

Additional evidence for the impact of current mental states on implicit learning comes from social psychology research on motivational states. This body of research typically contrasts two types of regulatory focus: approach of positive items and avoidance of negative items. These have been further generalized to describe motivational orientation in terms of either a promotion (gain focused) or prevention (loss focused) framework. Within this framework, individuals with a promotion focus tend to concentrate on attaining correct responses in a given task, whereas those with a prevention focus put more effort into avoiding incorrect responses (Higgins, 1997). Furthermore, task structure can interact with regulatory focus to provide either a regulatory fit (e.g., earning a reward + promotion focus) or a regulatory mismatch (e.g., avoid losing a reward + promotion focus).

Grimm, Markman, Maddox, and Baldwin (2008) examined regulatory fit effects on category learning and reported dissociable

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Preliminary accounts of the data were presented as posters at the Chicago Area Undergraduate Research Symposium and the L. Starling Reid Undergraduate conference at University of Virginia.

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effects on implicit and explicit learning. Participants' regulatory focus was manipulated by motivating participants either to seek gain or avoid loss, and positive/negative feedback was manipulated separately. They reported that regulatory mismatch produced better implicit learning while regulatory match produced better explicit learning. The authors speculated that a regulatory fit promotes flexible problem solving, which is beneficial in a rule-based task but can hinder implicit learning of more complex categories. However, visual category learning tasks are amenable to multiple strategies, complicating the interpretation of how implicit and explicit learning are affected by these manipulations.

In the current studies, we followed the regulatory fit design of Grimm et al. (2008) to examine the effect of motivational manipulations on implicit sequence learning, using our relatively more process-pure implicit task (the SISL task). Based on their results, we predicted in Experiment 1 that individuals experiencing a regulatory mismatch would show superior implicit learning. Experiment 2 was a replication of Experiment 1 while also investigating whether regulatory fit/mismatch affected learning or expression of knowledge on the SISL task.

Experiment 1 Method

Participants

One hundred twenty-five participants were compensated $10/hour for participation. The study had an age limit of 18–55 years of age. This study was approved by Northwestern University's Institutional Review Board, and participants provided written consent in accordance.

Materials

The SISL task. The SISL task was implemented largely as in previous research (e.g., Sanchez, Gobel, & Reber, 2010; Sanchez & Reber, 2012; 2013). For this task, cues move vertically down the screen at an initial rate of 376.6 pixels/second (i.e., 1.5 seconds from cue appearance to target interception) and the participants were instructed to attempt to intercept the cues by pressing a corresponding key (shown: D, F, J, K) when the cues overlapped a target ring. Responses were scored as correct if the corresponding key was pressed when the cue overlapped the target ring within 141 pixels to the target on either side of the optimal target response. The wrong key response, incorrect response timing, and multiple keypresses within one response window were all considered incorrect responses. Feedback is generally provided by flashing the target ring green for a correctly timed response and flashing the ring red for an error. This was altered based on condition in Experiment 1 as described below.

Participants were not told that the cues tended to follow a covertly embedded repeating sequence 12 items long. A different repeating sequence was randomly assigned to each participant. All repeating sequences were constrained to not include repeat cues (same response on successive trials). Each of the four possible responses occurred equally often, and the repeating structure was based on second-order conditional (Reed & Johnson, 1994) probability (e.g., D F D J K F J D K J F K). Furthermore, the sequence had a consistent sequence of cue interstimulus intervals (ISIs) that included six long ISIs (750ms) and six short (350 milliseconds) ISIs arranged randomly. During training practice, the cues followed the repeating sequence 80% of the time (four repetitions within each 60-trial subblock) and the remaining 20% of the time were novel nonrepeating second-order conditional sequences.

Cues' speed was adjusted adaptively to maintain a task overall performance rate targeting 75% correct. Initially cues reached the target zone 1.5 seconds after appearing on the screen, and from this rate if performance exceeded 80% correct over 20 trials, the speed was increased by 5%. If performance fell under 70%, speed was decreased 5%. Cue ISI was adjusted to be consistent with overall speed changes (the relative gaps between cues remained constant; the whole task sped or slowed together).

Procedure

SISL task. All participants completed a 3240-trial SISL task training session organized into six 540-trial blocks. Each training block contained 36 repetitions of the 12-item sequence and nine 12-item nonrepeating sequences in a pseudorandom order. Following training, participants completed a 540-trial SISL test block to assess sequence-specific learning. No indication of the start of the test block was given to participants, and the speed was fixed at the rate of the last training block before the test. The test block consisted of 15 repetitions of the training sequence and 15 repetitions each of two novel foil sequences in a pseudorandom order. The test provided the key dependent variable—the difference in performance (percent correct) for the training sequence and the average performance on the two unfamiliar sequences, referred to below as the Sequence Specific Performance Advantage (SSPA).

The four conditions in the 2 $\times$ 2 design included the following: approach-match (approach motivation + positive feedback; $N = 35$), avoidance-match (avoidance motivation + negative feedback; $N = 34$), approach-mismatch (approach motivation + negative feedback; $N = 25$), or avoidance-mismatch (avoidance motivation + positive feedback, $N = 33$). Participants were randomly assigned to one of these four conditions. Feedback was manipulated such that participants received either only positive or only negative feedback on their responses (i.e., only green flashes for correct responses and nothing for errors or only red flashes on incorrect responses and nothing for correct responses). In addition, during the positive feedback condition, positive verbal phrases (e.g., correct!; great!; or excellent!) flashed across the screen for every third correct response. For the negative feedback condition, red negative verbal phrases (e.g., missed, try harder, or wrong) flashed across the screen for every incorrect response.

The two motivation conditions were manipulated based on instructing participants that at the completion of the experiment, they would have a chance to receive tickets for a cash drawing of $50 based on their performance in addition to their original $10 compensation. In the approach condition, participants were informed that they could earn up to two tickets, depending on their overall task performance and that a positive, growing progress bar (see Figure 1) on the right side of the screen tracked their performance toward their goal of winning both tickets. In the avoid condition, the participants were told that they would start with two tickets toward the cash drawing and that their performance could lead to losing these tickets if they made too many errors. In this condition, they were told that a negative, decreasing progress bar on the right side of the screen tracked their performance toward losing the tickets. Movement of the progress bar was controlled based on the 75% correct response rate (controlled by

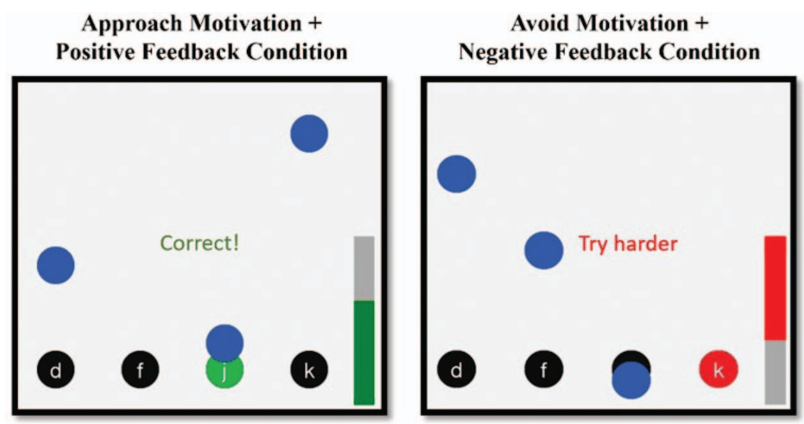

Figure 1. SISL task for Experiments 1 and 2. The figures shown above reflect the two match conditions. For Experiment 2, the verbal phrase feedback was removed.

adaptive speed adjustments as described above) so that it reached the top or bottom of the bar (for both approach or avoid conditions, respectively) by the end of the experimental session. Thus, the bar was incremented for every incorrect response in the avoid conditions and every third correct response in the approach conditions. The task was still adaptively controlled to maintain an overall 75% correct performance rate regardless of condition.

Only participants who maintained good overall task performance without excessive missed trials were included in the main analysis. Participants who missed more than 50% of trials within a block of 540, or whose overall performance led to an unusual amount of task slowing (>2 seconds from onset to target) were excluded. In addition, participants with performance of less than 40% correct during the crucial test foil blocks were excluded because this both artificially inflates SSPA scores and reflects a lack of attention to the task. The exclusion criteria were prespecified and recruiting targeted 20 participants per condition (i.e., 80 participants total). This was done to match typical sample sizes used in previous studies with the SISL task (e.g., Thompson et al., 2014). A power analysis was not conducted because the motivation/feedback manipulation had not been used with the SISL task (or any similar task) in previous studies. From the original 125 participants, 45 were excluded (15 were from the approach-match condition, 5 from the approach-mismatch condition, 13 from the avoid-match condition, and 12 from the avoid-mismatch condition), leaving the targeted total of 80 participants for the following analyses. The small number of participants excluded from the approach-mismatch condition compared to the other three is of potential interest, although the distribution of excluded participants was not quite statistically significant ($\chi^2 = 3.38$, $p = .066$). However, the lower exclusion rate in this condition is somewhat difficult to interpret, given that the other mismatch condition was more similar to the match conditions in its exclusion rate.

Recognition task. Following training, participants were informed about the presence of a repeating sequence and their explicit knowledge of this sequence was measured with a recognition task. Participants were presented with the trained repeating sequence and four novel foils in a random order and asked to rate each sequence from 1 (*sure they had not seen the sequence during training*) to 9 (*sure they had seen the sequence during training*). A recognition score for each participant was calculated as the difference between their rating for the trained sequence and their average rating for the four foil sequences.

Debriefing

Following the experiment, participants were informed that they would all receive two tickets for the raffle drawing, regardless of their actual performance. The raffle drawing for $50 was carried out after every 10 participants.

Experiment 1 Results

SISL Task

The amount of implicit learning that occurred during sequence practice is assessed using the SSPA observed during the test. A 2 × 2 ANOVA examined the impact of the motivation (avoid and approach) and feedback conditions (positive and negative) on SSPA (see Figure 2). There was a main effect of motivation, $F(1, 76) = 5.79$, $p = .019$, $\eta_p^2 = .07$, reflecting the fact that participants in the avoid motivation conditions exhibited greater sequence-specific knowledge ($M = 14.64\%$, $SE = 1.95\%$, 95% confidence interval [CI] = [10.8%, 18.5%]) than those in the approach motivation conditions ($M = 8.08\%$, $SE = 1.88\%$, 95% CI = [4.2%, 11.9%]). No reliable main effect of feedback condition (positive feedback, $M = 10.28\%$, $SE = 2.01\%$, 95% CI = [8.6%, 16.3%]; negative feedback, $M = 12.44\%$, $SE = 1.94\%$, 95% CI = [6.4%, 14.1%]; $F(1, 76) = 0.63$, $p > .250$), nor any interaction between feedback and motivation, $F(1, 76) = 0.28$, $p > .250$ was observed.[1]

[1] The 2 × 2 analysis of motivation and feedback effects on implicit learning was repeated with a follow-up analysis including all 125 participants (i.e., including the very noisy measures produced by participants otherwise filtered for low task compliance). The reliable main effect of avoid motivation enhancing learning rate was also evident in the larger sample, $F(1, 121) = 4.45$, $p = .037$, $\eta_p^2 = .04$, also reflecting the fact that participants in the avoid motivation conditions exhibited greater sequence-specific knowledge ($M = 17.98\%$, $SE = 1.92\%$, 95% CI = [14.2%, 21.7%]) than those in the approach motivation conditions ($M = 12.09\%$, $SE = 1.93\%$, 95% CI = [8.2%, 16.1%]). Again, no reliable main effect of feedback condition, $F(1, 121) = 0.61$, $p > .250$, or any interaction between feedback and motivation, $F(1, 121) = 0.33$, $p > .250$ was observed.

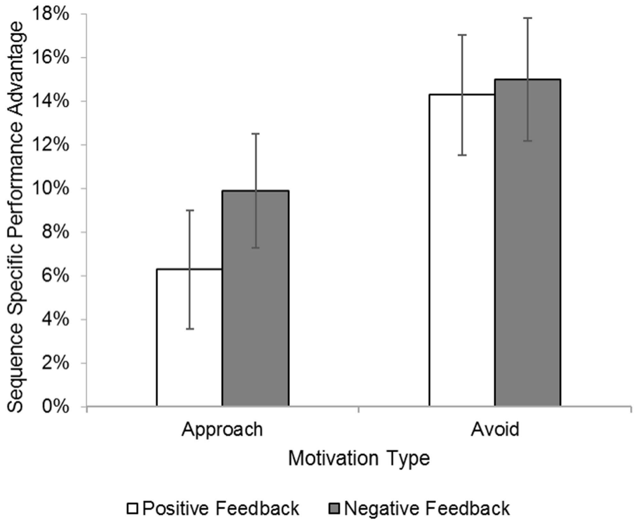

Figure 2. SISL test performance for Experiment 1. The sequence-specific performance advantage measures the benefit to SISL task performance when cues are following the trained repeating sequence (calculated as the difference in percent correct for the trained sequence minus percentage correct for the untrained sequences). Error bars reflect the standard error of the mean.

It is worth noting that an interaction between training block and motivation condition was not observed during training, $F(5, 72) = 0.57$, $p > .250$, nor was there a main effect of motivation during the last training block, $F(1, 76) = 0.08$, $p > .250$. However, this likely has to do with the structure of the training blocks themselves. First, there are far more repeating sequence trials than foil trials (80% vs. 20%, respectively). Additionally, the foil sequences do not repeat during training as they do at test, making these foil sequence an improper baseline for comparing performance on the trained sequence. By contrast, the test block is designed to give a more accurate measure of the performance advantage for the training sequence by comparing three repeating sequences—the training sequence and two novel foil sequences—and it is not surprising that group differences only emerged during this block.

We also performed a 2 × 2 ANOVA using the speed achieved by participants at the test block. The task speed that produces the target overall 75% correct performance during training ($M = 0.79$ s, $SE = 0.05$) varied across participants, reflecting differing aptitudes or experience with the game-like SISL task. No reliable effects of motivation, $F(1, 76) = 0.53$, $p > .250$ or feedback, $F(1, 76) = 0.26$, $p > .250$ on speed were observed nor was the interaction reliable, $F(1, 76) = 1.00$, $p > .250$, although the participants in the mismatch conditions tended to have higher (i.e., slower because speed was measured as time to target) speed (approach-mismatch: $M = 0.84$ seconds, $SE = 0.05$, 95% CI = [0.75 seconds, 0.93 seconds]; avoidance-mismatch: $M = 0.78$ seconds, $SE = 0.05$, 95% CI = [0.69 seconds, 0.87 seconds]) than the participants in the match conditions (approach-match: $M = 0.77$ seconds, $SE = 0.05$, 95% CI = [0.68 seconds, 0.86 seconds]; avoidance-match: $M = 0.76$ seconds, $SE = 0.05$, 95% CI = [0.67 seconds, 0.85 seconds]). However, this difference was not significant, $t(78) = 1.01$, $p > .250$.

Additionally, all conditions displayed similar overall performance at test (approach-match: $M = 65.80\%$, $SE = 2.88\%$, 95% CI = [61.0%, 70.5%]; avoidance-match: $M = 64.01\%$, $SE = 2.15\%$, 95% CI = [59.3%, 68.7%]; approach-mismatch: $M = 61.55\%$, $SE = 2.38\%$, 95% CI = [56.8%, 66.3%]; avoidance-mismatch: $M = 63.70\%$, $SE = 1.96\%$, 95% CI = [59.0%, 68.4%]), reflected by the lack of a main effect of either motivation, $F(1, 76) = 0.01$, $p > .250$ or feedback, $F(1, 76) = 0.68$, $p > .250$ on overall percent correct, nor an interaction between the two, $F(1, 76) = 0.92$, $p > .250$.

Recognition Task

Overall, participants tended to have some ability to recognize the repeating sequence as reflected by higher recognition ratings given to the practiced sequence ($M = 6.70$, $SE = 0.22$) than the foil sequences ($M = 4.94$, $SE = 0.15$, mean difference = 1.76 points on the 9-point scale, 95% CI = [1.21, 2.30]), $t(79) = 6.46$, $p < .001$. However, participants' recognition score (trained sequence rating minus average foil rating) did not correlate with their test SSPA, $r = .11$, $p > .250$, indicating that participants' performance on the SISL task was independent of explicit knowledge as found in previous studies using the SISL task (e.g., Sanchez et al., 2010; Sanchez & Reber, 2013). Furthermore, there was not a main effect of motivation, $F(1, 76) = 0.27$, $p > .250$, or feedback, $F(1, 76) = 0.01$, $p > .250$, on recognition score or an interaction between the two, $F(1, 76) = 0.49$, $p > .250$.

Experiment 1 Discussion

We did not find that regulatory mismatch led to greater implicit skill learning in the SISL task but did observe a robust main effect that avoid motivation led to a much greater performance advantage for the repeating sequence. This effect was specific to the trained repeating sequence and was not reflected in improved overall performance (measured either by accuracy or test speed), but the improved test performance does not indicate whether the learning rate was enhanced or whether the expression of sequence-specific knowledge was improved. In Experiment 2, we aimed to replicate the enhancing effect of avoid motivation while also assessing whether the motivation effect reflected an increased learning rate or a boost to test performance.

Experiment 2 Method

Participants

One hundred eight participants were compensated $10/hour for participation. The study had an age limit of 18–55 years of age. This study was approved by the Northwestern University's Institutional Review Board, and participants provided written consent in accordance with institutional review board policy.

Procedure

Participants were randomly assigned to one of two motivation conditions: approach ($N = 56$) or avoid ($N = 52$) with the same presentation and instructions as Experiment 1. For all participants, correct cues flashed green and incorrect cues flashed red (no verbal phrases with additional feedback were used as we found no effect of feedback in Experiment 1). Participants completed a 3240-trial SISL task training and a 540-trial test block (as in Experiment 1).

After completing the main part of the experiment, the experimenter debriefed the participants concerning the motivation manipulation and explained that they would receive an equal chance at the cash drawing, regardless of their performance. Participants were then asked whether they would volunteer to complete another test block with no additional reward or further gain. This second 540-trial SISL test was technically optional (because it followed debriefing) and took approximately an additional 5 min but allowed us to measure sequence-specific performance that was no longer affected by any motivation manipulation. If motivating participants to avoid loss increased the learning rate, we should observe better performance for that condition on the first test block and also this final unmotivated block. If the effect of avoid motivation is to enhance performance, we should observe better test performance (as in Experiment 1) in the first block, but this effect should no longer be present in the second test block when motivation is no longer present. Participants were not given a recognition task as in Experiment 1 because we did not find any motivational effect on explicit knowledge or any evidence that participants used their explicit knowledge of the sequence to perform the task.

As in Experiment 1, the primary analysis focused on participants with good overall task compliance (81 of 108 total). Our targeted sample size was 80 participants to match the sample size used in Experiment 1. In addition to 20 participants excluded for poor compliance, an additional seven participants elected not to continue the experiment to the second, optional test block administered after debriefing.

Experiment 2 Results

Data were analyzed with a 2 × 2 mixed-model ANOVA with motivation (avoid, approach) as a between-participants factor and test block (first, second) as a within-participant parameter. There was a reliable interaction between motivation condition and test block, $F(1, 79) = 4.26$, $p = .042$, $\eta_p^2 = .05$, reflecting a successful replication of the effect of manipulating motivation on the first test block but no difference in performance on the second, unmotivated test block (see Figure 3). On the first test block, there was a reliable difference in SSPA between the avoid motivation (M = 14.81%, SE = 1.77%) and the approach motivation conditions (M = 9.80%, SE = 1.69%; mean difference = −5.01, 95% CI = [−9.89, −0.15]); $t(79) = 2.05$, $p = .044$, $d = .46$). Across both blocks, there was no main effect of motivation (avoid, M = 12.06%, SE = 1.40%, 95% CI = [9.2%, 14.9%]; approach, M = 9.65%, SE = 1.40%, 95% CI = [6.8%, 12.5%]; $F(1, 79) = 1.42$, $p = .238$), but a main effect of block was observed (first test block, M = 12.34%, SE = 1.25%, 95% CI = [9.9%, 14.7%]; second test bock, M = 9.40%, SE = 1.15%, 95% CI = [7.1%, 11.7%]; $F(1, 79) = 5.27$, $p = .024$, $\eta_p^2 = .06$), reflecting the overall better performance on the first test driven by the avoid motivation group exhibiting greater sequence-specific performance.[2] Thus, the effect of avoid motivation appears to be better expression of acquired implicit knowledge and not a general increase in the implicit learning rate. Again, there was no interaction between training block and motivation condition, $F(5, 75) = 1.08$, $p > .250$.

As in Experiment 1, there were no significant differences in overall task performance as measured by test speed between the avoid and approach motivation conditions (avoid, M = 0.87 s, SE = 0.04, 95% CI = [0.80 s, 0.94 s]; approach M = 0.82 s, SE = 0.04, 95% CI = [0.75 s, 0.90 s]; $F(1, 79) = 0.74$, $p > .250$) or overall task performance on the test block (avoid, M = 70.81%, SE = 1.31%, 95% CI = [67.8%, 73.8%]; approach, M = 70.41%, SE = 1.28%, 95% CI = [67.4%, 73.4%]; $F(1, 79) = 0.04$, $p >$ .250). There was a main effect of test block on overall percent correct, ($F(1, 79) = 55.99$, $p < .001$, $\eta_p^2 = .42$), reflecting a general improvement in performance across these blocks when there were no longer any adaptive speed adjustments made to the task (first block: avoid, M = 65.75%, SE = 1.66%, 95% CI = [62.5%, 69.0%] and approach, M = 66.79%, SE = 1.74%, 95% CI = 63.4%, 70.2%]; second test block: avoid, M = 75.87%, SE = 1.72%, 95% CI = [72.5%, 79.2%] and approach, M = 74.02%, SE = 1.73%, 95% CI = [70.6%, 77.4%]).

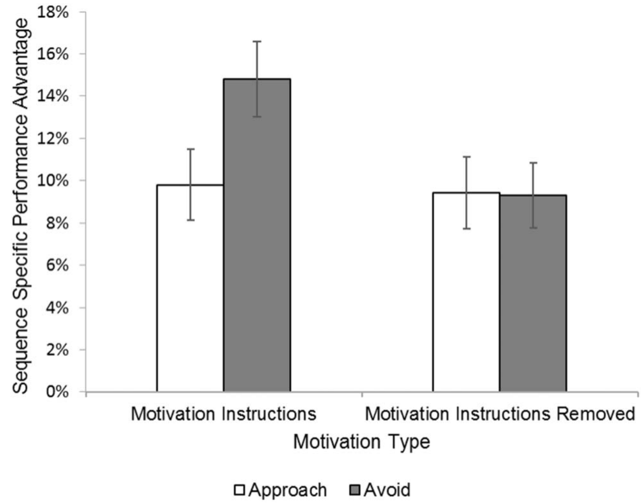

Figure 3. SISL test performance for Experiment 2. Participants who trained under the avoid motivation condition exhibited a greater sequence-specific performance advantage at test in block 7 during the motivated test. However, on a following test where motivation was released, no reliable differences in performance between groups was observed. Error bars reflect the standard error of the mean.

[2] When all low-compliance participants and low-compliance participants who opted out of the second, optional test were included in the analysis, the mean difference between motivation conditions was similar, with the avoid motivation condition (M = 15.33%, SE = 1.58%) still exhibiting higher implicit performance than the approach motivation condition (M = 12.25%, SE = 1.88%) on the first test block, but the additional variance in the low-compliance participants meant this difference was not statistically reliable in the whole sample, $t(101) = 1.26$, $p = .211$, for the first test block; $F(1, 98 = 1.44$, $p = .233$ for the interaction across blocks). Of note, these low-compliance participants had a high number of missed trials in both the first test block (M = 145.86, SE = 13.59) and the second test block (M = 96.47, SE = 15.41) and a low accuracy on the foil trials in both the first test block (M = 31.67%, SE = 2.01%) and the second test block (M = 41.79%, SE = 4.11%), which may explain why including their data diluted our effect. When the participants who were not low-compliance but did opt out of the second, optional test were included for analysis, the motivation effect remained marginally significant for the first test block, with the avoidance motivation (M = 14.81%, SE = 1.77%) condition exhibiting higher implicit performance than the approach motivation (M = 10.76%, SE = 1.69%) condition, $t(83) = 1.66$, $p = .100$.

General Discussion

Experiment 2 replicated the enhanced performance associated with avoid motivation while also indicating that this effect is largely due to better performance rather than faster learning. Whereas approach motivation participants' performance was similar to that seen in previous studies using SISL (e.g., Sanchez et al., 2010; Sanchez & Reber, 2012; Sanchez & Reber, 2013), avoid motivation participants performed significantly better under the motivation manipulation but not once this manipulation was removed. Thus, across two experiments, we found that motivation to avoid loss leads to robustly better skilled performance for a task that depends on implicit learning (Sanchez & Reber, 2013). The performance enhancement observed was specific to the covertly embedded repeating sequence and did not lead to better overall task performance as measured by overall accuracy or speed. This motivation effect challenges prior assumptions that implicit learning is generally associated with automatic performance not susceptible to manipulations of mental state. Rather, our novel finding implies that skilled performance, particularly of skills acquired implicitly, can be enhanced by manipulating motivational state.

Prior research on approach-avoidance motivation suggested that avoidance motivation tends to have stronger effects than approach motivation (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Elliot & Covington, 2001), which is in line with the results we observed. This effect is also demonstrated in cognitive control tasks requiring response inhibition or task switching (Koch, Holland, & van Knippenberg, 2008) as well as tasks requiring creative cognition (Friedman & Förster, 2002). The current experiments significantly add to the theoretical understanding of automatic processes and implicit learning. However, it might also be noted that the motivation effect was only evident on the sequence-specific measures during the final performance test and not reliable on measures collected during the training phase (either speed or the SSPA estimated from the 80/20 trial split), raising some additional interesting questions about conditions necessary to observe this effect. These findings not only motivates future research concerning automatic processes but also invites the possibility of identifying improved or ideal conditions for the successful expression of skilled implicit knowledge for real-world skills such as music and sports.

The phenomenon alluded to earlier of the tough coach may be due to the existence of this effect. Coaches or trainers seeking the best possible skilled performance may have explicitly or implicitly come to find that motivation to avoid loss (of status, scholarship, coaching access, etc.) produces better performance in competition. At the same time, extrapolation of this effect to nonlaboratory contexts needs to be considered in the context of choking effects (e.g., DeCaro, Thomas, Albert, & Beilock, 2011) in which high stress levels can produce worse performance. This seems to run counter to studies by Schwabe and colleagues (e.g., Schwabe & Wolf, 2013), who show that stress can promote habit (implicit) memory but harm explicit memory. However, an alternate possibility that would bring the research on choking effects in line with work by Schwabe et al. is that although implicit learning expression is potentiated by avoid motivation, explicit knowledge use is hampered, leading to poor performance in complex domains in which both types of memory need to be brought to bear (e.g., math tests; Beilock & DeCaro, 2007).

The mechanism by which motivation to avoid loss potentiates the expression of sequence-specific knowledge is not immediately clear. Studies of patients with Parkinson's disease have implicated dopamine-gated plasticity (Gobel et al., 2013; Siegert, Weatherall, & Bell, 2008) in learning. However, it seems that this would predict better learning for positive reward or approach motivation, which is the opposite of what was observed. Another possibility is that the powerful effect of motivation to avoid loss (Kahneman, Knetsch, & Thaler, 1991) brings a greater attentional focus to performance. This explanation runs counter to the frequently reported lack of effects of reducing attentional focus on implicit sequence learning (Frensch, Lin, & Buchner, 1998; Frensch, Wenke, & Runger, 1999; Schumacher & Schwarb, 2009) and is somewhat inconsistent with a lack of improvement in overall task performance during the test blocks. Instead, the results reported here appear to indicate a novel mental state effect mechanism that has not been previously reported in laboratory research, but that may be implicitly known to trainers attempting to elicit high performance levels.

The implication of the results reported here is that for a skilled performance task, more effective expression of implicitly acquired knowledge will be seen when performers are motivated to avoid loss. A robust performance effect was seen in both experiments. Experiment 2 indicates that this effect is specific to performance and does appear to reflect a change in the underlying learning process. Practice improvements likely proceed by repetition (Sanchez & Reber, 2012), but after practice, best performance is achieved when combined with the appropriate motivational state.

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