Qualitative Differences Between Implicit and Explicit Sequence Learning

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Four experiments investigate the differences between implicit and explicit sequence learning concerning their resilience to structural and superficial task changes. A superficial change that embedded the SRT task in the context of a selection task, while maintaining the sequence, did selectively hinder the expression of implicit learning. In contrast, a manipulation that maintained the task surface, but decreased the sequence validity, affected the expression of learning specifically when it was explicit. These results are discussed in the context of a dynamic framework (Cleeremans & Jiménez, 2002), which assumes that implicit knowledge is specially affected by contextual factors and that, as knowledge becomes explicit, it allows for the development of relevant metaknowledge that modulates the expression of explicit knowledge.

Keywords: implicit learning, sequence learning, learning and consciousness

In the burgeoning literature about implicit learning it has become common to describe implicit learning effects simultaneously as more robust and as more specific than their explicit counterparts (e.g., Berry & Dienes, 1993; Dienes & Berry, 1997; Reber, 1993; Stadler, 1997). The effects of implicit learning are usually described as more robust than comparable explicit effects because the former ones do “typically survive neurological and psychological insults that compromise conscious, explicit processes” (Reber, 1993, p. 18). At the same time, however, implicit knowledge is also characterized as more specific than explicit knowledge, because the expression of implicit knowledge appears to be less resistant to changes in its triggering conditions, and because it “tends to be less manipulable and more context bound” (Berry & Dienes, 1993, p. 13; but see Willingham, 1997, 1998b, for critical commentaries on the difference in flexibility between implicit and explicit memory).

These two features of implicit-learning effects may appear as mutually contradictory, because they simultaneously depict them as more resistant to some changes but as less resistant to others. Proponents of an episodic account of implicit learning have attempted to solve this paradox by describing implicit-learning effects as linked to the specific details of the learning episodes (Neal & Hesketh, 1997; Whittlesea & Dorken, 1993, 1997), whereas explicit learning would be characterized as more internally driven and dependent on the abstract elaboration processes that are typically hindered by neurological disorders. Consistent with these claims, but with a closer relation to the issues of consciousness, a recent proposal by Cleeremans and Jiménez (2002) has suggested that explicit representations may be distinguished from implicit representations by appealing to two functions of control. According to this proposal, these two types of knowledge may differ from each other in terms of their relative potency, or their capacity to exert control over any further processing going on in the system. In addition, they could also be distinguished in terms of a more passive function of control, referring to the availability of this knowledge to control operations. According to this framework, implicit representations are depicted as involving weak representations that exert little control over any further processing but that are still able to produce some behavioral effects, provided that they are activated in conjunction with an adequate set of simultaneous constraints. In addition, and precisely because of their relative small and diffuse effects, implicit representations run free from direct control influences. In contrast, explicit representations exert more powerful effects over the course of processing but, precisely because of that, they are also subjected to a much more direct control exerted from the rest of the processing operations.

From this graded view of conscious and unconscious influences, which may be seen as related to the notions of consciousness as a global workspace (Baars, 1988, 1997; Dehaene & Naccache, 2001), it is easy to understand why implicit influences tend to be simultaneously more robust and more specific than comparable explicit-learning effects. Given that implicit-learning influences are weaker than their explicit counterparts, they tend to be more dependent on the overall reinstatement of the conditions on which the relevant knowledge was acquired in the first place (cf. Fen-
drich, Gesi, Healy, & Bourne, 1995). Reciprocally, although explicit-learning effects can be maintained against a larger number of procedural changes with the aid of the appropriate strategic operations, they tend to be more dependent on the integrity of the cognitive structures that sustain these strategic operations, and are more affected by a breakdown in any of these functions.

The aim of the present study is to test some of the implications of this view within the well-developed paradigm of sequence learning. We will show that some contextual factors that do not compromise the structure of the sequence may have dramatic effects over the expression of implicit learning, although they leave explicit effects relatively unaffected. Conversely, we will also report on some manipulations that affect participants’ reliance on the learned structure when learning is explicit but that do not affect the expression of this learning when it remains implicit.

Sequence Learning

In the typical sequence-learning paradigm, participants are presented with a serial reaction time (SRT) task in which they are instructed to respond as quickly and accurately as possible to the location of a stimulus that is presented on each trial at one of several possible locations on a computer screen. Unknown to the participants, the series of locations follows a regular sequence, and the measures of performance show that, with practice, participants become progressively sensitive to this pattern. These results have been observed when the sequence is structured to follow a fixed and repeating series (e.g., Nissen & Bullemer, 1987; Willingham, Nissen, & Bullemer, 1989), as well as when it follows a complex set of rules from which several deterministic series can be generated (e.g., Lewicki, Hill, & Bizot, 1988; Stadler, 1989), or when the sequential structure is merely probabilistic (Cleeremans & McClelland, 1991; Jiménez, Méndez, & Cleeremans, 1996). In this latter paradigm, learning has been observed to proceed independent of participants’ intention to learn, as well as to produce dissociations that are most compatible with an interpretation of this knowledge as nonconscious (e.g., Jiménez et al., 1996).

The discussion about whether the knowledge acquired in these conditions can be applied while participants remain unconscious of its contents has proven to be very difficult to settle (Frensch, 1998; Shanks & St. John, 1994; Stadler, 1997). A host of methodological discussions has plagued the area, and it has motivated a growing number of researchers to move toward the search for a different way to characterize implicit knowledge. We surmise that a possible way out of this debate may start by substantiating the existence of qualitative differences between the knowledge acquired when participants are told to look for sequences (under intentional conditions) and when they are just trained to respond to each trial under incidental conditions, in the context of the SRT task.

In the present study, we will report on two series of experiments that analyze such differences over two types of transfer designs. Such designs have been commonly used in the sequence-learning paradigm either to assess the amount of learning acquired over a training period or to investigate the perceptual versus motor nature of this knowledge. For instance, the most common strategy to assess learning in this paradigm has been to change the structure over a transfer block and to assess whether this change produces a decrement in the measures of performance (e.g., Cohen, Ivy, & Keele, 1990; Curran & Keele, 1993; Mayr, 1996; Reed & Johnson, 1994). In a related design, it has also been usual to analyze the perceptual versus motor nature of this learning by training participants with a sequence that features both motor and perceptual regularities, then presenting them with a transfer block in which only one of the two possible components of the sequence is maintained (Cohen et al., 1990; Keele et al., 1995; Mayr, 1996; Stadler, 1989; Willingham, 1999; Willingham, Wells, Farrel, & Stemwedel, 2000).

Our aim in this study is to manipulate the nature of learning through intentional and incidental instructions and to use two new types of transfer designs to investigate the differences between the learning produced in these conditions. In the first series of experiments we tested for the specificity of this learning by introducing a transfer block in which the sequence was kept constant, but another change was arranged to alter the learners’ reliance on the previously acquired knowledge. Specifically, we changed the complexity of the task by making it a selection task, that is, by adding distractors that appeared at each of the nontarget locations to make it more difficult for participants to search for the relevant target. Our hypothesis was that if participants in the intentional condition were able to acquire explicit knowledge of the sequence, then they could easily notice that the sequence did not change over this transfer block; hence they would be expected to keep using their knowledge to carry out a more efficient search for the target stimulus among distractors. On the contrary, if participants presented with incidental conditions learned the sequence in a more implicit way, and if this implicit knowledge is more context-dependent, we may expect that the changes introduced over this transfer block could produce interference over the expression of learning, even though both the sequence of targets and the series of responses remained unchanged.

As for the second series of experiments, we arranged another transfer setting designed to produce complementary effects to those hypothesized for the first experimental series. In this series, the introduction of the transfer blocks was not marked in any explicit way, and participants were required to keep performing the same task as before. Just as it is usually done in the standard deterministic paradigm, at some point in training, participants were presented with a number of control blocks featuring a new sequence. However, and at variance with these standard procedures, we interspersed a number of trials generated according to the training sequence in the middle of these control blocks. We expected that if participants in the intentional condition were able to develop explicit knowledge about the sequence, they would surely notice that their knowledge was no longer valid over this transfer block; hence they would develop an attentional set directed to avoid being misled by this irrelevant knowledge. This would produce a slowdown in responding not only to control trials but also to those trials that conformed to the training sequence in the context of the transfer blocks. In contrast, if incidental learners acquired a more implicit knowledge, they would not be expected to notice the validity change introduced over the transfer block; thus they could keep on responding faster to the sequential trials even when they are presented in the context of this transfer block, which makes the learned sequence no longer valid.
Experiment 1

Before introducing the intentional versus incidental manipulation, we designed an experiment intended to assess the effect that including a selection task would have on the expression of the sequence learning acquired over training with a standard SRT task. We used a variation of the probabilistic sequence-learning paradigm introduced by Schvaneveldt and Gomez (1998), in which the stimuli followed a training sequence of locations on most trials, but where stimuli generated from a different control sequence replaced those generated by the training sequence on a small proportion of trials. At variance with the procedure developed by Schvaneveldt and Gomez, we presented complete sequences for both training and control trials to allow participants to be exposed to whole series, as usually occurs in comparable deterministic paradigms (see Jiménez & Vázquez, 2005, for another study using this procedure). We decided to do that because one of the aims of this experimental series was to manipulate participants’ intentions, and we reasoned that the continuous interruption of the training series with the appearance of isolated control trials could increase the likelihood that intentional learners would give up their intentional strategies and adopt a more passive orientation toward the SRT task.

Participants in the no-transfer condition were presented with 14 training blocks following this probabilistic structure, whereas participants in the transfer group were presented with exactly the same structure, except that in block 13 they were transferred to a selection task, in which they were to search for the target that was now presented along with some distractors that filled the nontarget locations.

Method

Participants. Thirty-two students from the University of Granada participated in the experiment in exchange for course credits, and they were randomly assigned to the transfer or nontransfer condition. They had never participated in similar experiments before.

Apparatus and materials. The sequence of stimuli was generated by a personal computer and presented on a 14-inch screen. The program that controlled the experiment was written using INQUISIT 1.31 software. The participants responded (using a keyboard placed in front of them) by pressing one of four possible keys marked as response keys. Two analogous second-order conditional (SOC) sequences (Reed & Johnson, 1994) were used to generate the series of trials. Both contained a series of 12 locations and were counterbalanced across participants as either the training or control sequences. If we refer to the target locations from left to right with the letters A to D, the sequences were as follows: SOCa: A-B-A-D-C-B-D-A-C-D-B-C; and SOCb: C-B-C-D-A-B-D-C-A-D-B-A. As can be observed, in both sequences each location appears with the same likelihood, and each first-order transition (with the exception of repetitions, which are forbidden) is also equally likely. In addition, the SOCs include a minimum of reversals (one per sequence, as in A-B-A), and they are maximally discriminative between sequences so that the successor of any given context is always different between SOCa and SOCb. In fact, both sequences are structurally identical to each other and are related by a simple transformation A\(<\rightarrow>C.

Procedure

The target stimulus was always a random even number (2, 4, 6, or 8) that appeared on each trial at one of four possible locations distributed over the horizontal axis of a computer screen. Four horizontal short lines were presented just below the four locations where the stimuli could appear, being the distance between each pair of adjacent locations 3.5 cm. Participants were instructed to respond to the location of the stimulus regardless of its identity, by pressing on a key that was spatially compatible with its location. The response keys were those of the letters Z, X, N, and M on a Spanish keyboard. The position of the stimuli had a consistent spatial correspondence with these response keys so that the participants had to press the Z key when the stimulus appeared at the leftmost location, the X key when it was the next location to the right, and so forth.

After the instructions, the participants were presented with an initial series of 14 trials in which the locations were random. After that, they were given 14 blocks of 120 trials, which featured eight repetitions of the training sequence, together with two repetitions of the control sequence. Half of the participants were presented with SOCa as their training sequence; the other half were given the training sequence SOCb. Each block started with a token of the training sequence, with its starting point chosen randomly by the experimental program. From here on, the next series of 12 trials could follow the training sequence with a probability of .80 and the control sequence with a probability of .20. If the program had chosen no control series over the first four series, the fifth one was forced to feature a token of the control sequence. Likewise, if the control series had appeared only once after the first 9 series, then the 10th one was forced to follow the control SOC. In all cases, the transitions between series were linked in such a way that the last two locations of each sequence could be used to predict the first location of the following one. This connection made it possible to maintain the SOC structure during all the trials of each block.

The no-transfer group performed this task over 14 consecutive blocks of 120 trials, and learning was assessed as the progressive difference in both accuracy and RTs between responding to the frequent and infrequent sequences. For the transfer group, a transfer phase was included over the block 13, in which participants were informed that three odd numbers (1, 3, 5, or 9) were to appear over the nontarget locations, but that they were required to search for an even number among these three odd numbers and to keep responding on the location of this even number. Therefore over this transfer block the task was made more difficult by including a selection task, but both the sequence of target locations and the required series of motor responses remained unchanged (and so were the condition-action rules that were needed to respond to the SRT task, cf. Willingham et al., 1989). The only difference between training and transfer blocks was the embedding of the SRT task in the context of a more complex selection task, which required participants to discriminate among four different stimuli before pressing the key corresponding to the target location. After this transfer block, participants were informed that the conditions presented over the previous blocks would be restored, and they were presented with a single-stimulus task over the final block.

Results

For each block, the first two trials were discarded as warming trials. Mean RT on correct responses and percentage of errors were computed separately for training and control trials. The error rate was generally low (slightly below .04), and the trends detected over this measure did generally mirror those from RT. In the crucial analyses concerning the effects of sequence there was no indication of a trade-off between speed and accuracy that could unduly pass for an effect of learning; hence we focused on RT as the main indirect measure of sequence learning. However, we will report on the effects observed on error rates whenever they may introduce a difference in the interpretation of the effects of training.
**Indirect Measures**

A mixed analysis of variance (ANOVA) conducted on the measures of RT over the first 12 blocks with condition (transfer vs. no-transfer) as a between-participants factor and block (1 to 12) and sequence (training vs. control) as within-participants variables showed no effect of condition, but it produced strong effects of sequence, $F(1, 30) = 62.40, MSE = 280,756.83, p < .0001$ and block, $F(11, 330) = 9.99, MSE = 18,151.01, p < .0001$, as well as a significant sequence $\times$ block interaction, $F(11, 330) = 2.97, MSE = 3,893.73 p < .001$. The fact that this interaction was not modulated by condition ($F < 1$) can be taken as evidence that both groups learned similarly about the trained sequence. As can be observed in Figure 1, this result can be interpreted as reflecting an effect of sequence learning that arose similarly in both groups over the first training blocks, and that was substantially maintained over the following blocks. The results on the error rates showed that errors increased over blocks from an average of .023 over the first block to .047 over the block 12, $F(11, 330) = 2.38, MSE = .003, p < .01$. This may be taken as showing a trade-off between speed and accuracy, but the effect of sequence was also significant in the analysis of error rates, $F(1, 30) = 21.58, MSE = .052, p < .0001$, thus showing that responses to training trials produced not only faster responses but also a smaller rate of errors than that found in responding to control trials (.027 vs. .044). The interaction of sequence $\times$ block did not approach significance in the analysis of error rates.

The analysis of block 13 also showed an interesting pattern. As can be observed in Figure 1, participants in the no-transfer group kept performing in much the same way as they did over the previous and the following block. However, participants presented with distractors over this transfer block needed twice as much time to respond to this new task as they needed to respond to the standard SRT task. Moreover, the effect of learning that was evident up to the previous block was completely removed over this transfer block, despite the fact that knowing the location of the next target stimulus might have produced an advantage in performance, by orienting participants to the right location, and thus avoiding the need to undertake a serial search over the distractors. The ANOVA conducted on the measures of RT obtained at block 13 with condition (transfer vs. no-transfer) and sequence (training vs. control) as independent variables showed a significant effect of condition, $F(1, 30) = 208.57, MSE = 5,772,946.71, p < .0001$, and a significant interaction of sequence $\times$ condition, $F(1, 30) = 7.54, MSE = 15,414.73, p = .01$. Separate analyses for transfer and no-transfer groups showed that the effect of sequence was significant in block 13 for the no-transfer group, $F(1, 15) = 19.25, MSE = 15,827.00, p < .001$, but not so for the transfer group ($F < 1$). Indeed, the net effect in this latter group went in the opposite direction, producing an average RT slightly faster for control than for training trials (1,009 vs. 1,026 ms). The analysis conducted on the error rates over this transfer block did not produce any significant effect or interaction. Finally, the analyses conducted on the block 14, where the training conditions were reinstated for both groups showed effects of sequence on both RT, $F(1, 30) = 27.89, MSE = 31,290.65, p < .0001$, and error rates, $F(1, 30) = 11.88, MSE = .017, p < .01$, but no effects or interactions involving condition. Therefore at the end of training all participants produced less errors (.023 vs. .056), and faster responses (397 vs. 441 ms) to training trials as compared with control trials.

**Discussion**

The results of Experiment 1 are straightforward. They showed that the probabilistic paradigm arranged in this experiment does produce sequence learning of the training pattern and that learning...

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**Figure 1.** Mean reaction times (RT) across training and transfer blocks for both control and experimental groups in Experiment 1. Filled marks correspond to trials generated according to the training sequence and open marks to trials that follow the control sequence. For the experimental condition, block 13 was designed as a transfer block in which the serial reaction time (SRT) task was embedded in the context of a selection task.
can be observed by comparing the mean RTs produced in response to the training versus control trials over the same blocks. In addition, these results also showed that the effect of learning observed at the end of block 12 did not survive the transfer manipulation introduced over block 13 for the transfer group, which required participants to produce the same sequence of motor actions in response to the same physical stimuli but embedded in a more complex context that required participants to search for the target among a set of distractors.

We surmise that this pattern of results is indicative that the learning obtained in these conditions was implicit. A conceptual analysis of the selection task suggests that, if participants would have become aware of the sequence, they could have taken greater advantage of this knowledge to cope with the selection task than to respond to the simpler SRT task. Indeed, if participants were able to explicitly anticipate the location of each target, we should expect that this knowledge could be used by participants to improve the efficiency of their search and hence to respond faster when the target appeared at the predicted location, as compared with those trials in which the even number appeared at the control location.

Although these results are suggestive of an implicit-learning pattern, in Experiment 1 there was no direct manipulation of awareness; therefore we have no independent proof that this learning was implicit. In Experiment 2 we sought to replicate this pattern of results and to test the prediction that, when learning becomes explicit, it can be strategically deployed so as to keep producing systematic effects on the selection task.

**Experiment 2**

The main goal of Experiment 2 was to test the prediction that explicit learners can use their sequence learning even when they are transferred from the standard SRT task to a selection task. We compared two groups of learners who were given either incidental instructions to perform the SRT task or intentional instructions to look for sequences. In an attempt to increase the likelihood that participants presented with intentional instructions would rely on their explicit attempts to learn the sequence and keep using their knowledge despite the fact that the sequence was only probabilistic, we adopted a different disposition for the locations, which we believe produces a more salient pattern than that made by the standard linear setting. Some previous studies have found that intentional instructions may fail to produce any difference in sequence learning when the sequence is complex and probabilistic (Jiménez, Méndez, & Cleeremans, 1996), arguably because both the speeded nature of the task and the continuous appearance of random patterns strongly press participants to resort to a passive strategy. In those circumstances, it appeared reasonable to take some additional steps to increase participants’ confidence on the intentional condition.

Therefore we used a squared design in which the relevant stimuli appeared on each trial at one of the four corners of an imaginary square centered on the screen. Considering A, B, C, D respectively as the upper-left, upper-right, lower-left and lower-right corners of the square, the SOCb featured the highly salient fragment ABDCa, which starts at the upper-left location and runs through the four corners of the square in a clockwise direction, to return to its origin at the fifth trial. We assumed that this salient pattern, together with the reversal pattern produced by the fragment CBC, could be easily tracked, and thus might be used by the intentional learners as effective anchors to parse the whole structure. Because the aim of our intentional manipulation was not only to compare the effect of incidental versus intentional instructions but also to make sure that participants in the intentional condition would keep trying to break through the repeated structure, we assigned SOCa systematically to all intentional learners, and started each block with the salient “clockwise-run” (ABDCA).

Participants in the intentional condition were thus presented with these special conditions, were instructed about the existence of a regular sequence, and were urged to try to discover and use this regularity as a way to optimize their performance. Participants in the incidental condition were all presented with SOCa without such intentional instructions, and for them each block started at a random point within this training sequence. The remaining procedural details were similar to those described for Experiment 1, except that a generation task was added at the end of training to directly analyze the amount of explicit learning that was acquired under each of these conditions.

**Method**

Participants. Fifty-six participants from the University of Santiago participated in the experiment in exchange for course credits. None of them had participated in similar experiments before, and they were randomly assigned to the intentional or incidental conditions.

Procedure. As in Experiment 1, the target stimulus was always a random even number (2, 4, 6, or 8). In this experiment, however, the stimulus appeared on each trial at one of the four corners of a 2.7 × 2.7-cm imaginary square centered on the computer screen. The square was not actually drawn, but an X appeared as a fixation point at the center of the screen, and four horizontal short lines were presented just below the four locations where the stimuli could appear. Participants were instructed to respond to the location of the stimulus regardless of its identity, by pressing on a key that was spatially compatible with its location. The response keys were those corresponding to the letters F, V, H, and B on a Spanish keyboard. The position of the stimuli had a consistent spatial correspondence with these response keys so that the participants had to press the F key when the stimulus appeared at the upper-left location, the V key when it was the lower-left location, the H key when it appeared at the upper-right location, and the B key when it was presented at the lower-right location. Participants maintained their middle and index fingers of the left hand steadily over the F and V keys, and the corresponding fingers of their right hand over the H and B keys.

In both conditions, participants were first presented with an initial series of 14 trials in which the locations were random. After that, they were given instructions appropriate to their condition. Participants in the intentional condition were instructed about the existence of a regular sequence and were urged to try to discover and use this regularity as a way to optimize their performance. Participants in the incidental condition were not provided with such instructions. All participants were then presented with the set of 12 training blocks of 120 experimental trials, featuring eight repetitions of the training sequence, and two repetitions of the control sequence. After these 12 blocks, participants were informed about the transfer conditions arranged over block 13. They were told that they should keep

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1 An additional ANOVA of the results of Experiment 1 including training SOC (a vs. b), in addition to the factors of Condition, Sequence, and Block, showed no effect or interaction depending on the training SOC, suggesting that learning did not depend on the specific SOC presented over training.
responding in much the same way to the location of the even number, but that three odd numbers (1, 3, 5, or 9) would now appear on each trial filling the nontarget locations. At the beginning of block 14, participants were told that the conditions observed over the first 12 blocks would now be restored. After block 14, they received instructions to complete a generation task.

Over this generation task, all participants were informed about the fact that the stimuli presented over the SRT task followed a complex, probabilistic sequence, and that the aim of this final task was to test whether they had become able to explicitly anticipate the most frequent successor of each series. Participants were then exposed to 96 series of six trials divided in two halves of 48 series, which corresponded to inclusion and exclusion conditions. The order of presentation for inclusion and exclusion conditions was counterbalanced across participants.

In every series of the generation task, the first five trials corresponded to trials featuring a fragment of either the training or the control sequence, to which participants responded in a speeded way, just as they did during the SRT task. The sixth trial of each series was arranged as a generation trial, consisting of two question marks located either at the location corresponding to the more frequent successor of this fragment or at the location corresponding to the successor of the two final items of that fragment according to the alternative sequence. Although we were primarily interested in knowing how participants generated the successors of their training sequence, we also used fragments of the control sequence to avoid providing new sequence information over this task. Participants under both inclusion and exclusion instructions responded two times to each of the 12 fragments that can be made out of their training sequence, and two times to each of the 12 fragments that can be made out of their control sequence, for a total of 48 series under inclusion instructions and another 48 series under exclusion instructions. In the inclusion conditions, participants were told to respond to these generation trials by choosing between the two locations marked with question marks and pressing on the key corresponding to the most frequent successor of the series. In the exclusion conditions, they were told to choose between the same two candidates but to press on the key corresponding to the less frequent successor of the series.

Results

SRT task. As in Experiment 1, the first two trials for each block were considered as warming trials and were not considered. For each block, mean RT for correct responses and error rates were computed separately for training and control trials. As in Experiment 1, the main conclusions concerning sequence learning were drawn from the measures of RT, but we analyzed the measures of accuracy to make sure that the trends showed in RT were not caused by a trade-off between speed and accuracy.

Percentage of errors. Participants’ performance was generally accurate, with an average proportion of errors below .04. An ANOVA conducted over the first 12 training blocks with condition (intentional vs. incidental), block (1 to 12), and sequence (training vs. control) as independent variables showed no effect of condition, but it produced strong effects of sequence, F(1, 54) = 275.67, MSE = 517,081.36, p < .0001, and block, F(11, 594) = 8.09, MSE = 13,192.08, p < .0001, as well as significant interactions of sequence × condition, F(1, 54) = 36.99, MSE = 69,378.86, p < .0001, and of sequence × block, F(11, 594) = 7.82, MSE = 6,558.24, p < .0001. The condition × sequence × block three-way interaction did not approach significance, indicating that the difference between conditions in the effect of sequence did not reflect a higher rate of learning for intentional learners. As can be observed in Figure 2, this difference appears from the beginning of training, and it does not reflect a trend for intentional learners to respond faster to those trials that follow the sequence, but rather a strong tendency for these learners to respond slower to control trials. An ANOVA conducted selectively with control trials confirmed this impression by showing significant effects of condition, F(1, 54) = 6.76, MSE = 169,866.35, p < .05, and block, F(11, 594) = 2.24, MSE = 3,739.52, p < .05, but not an interaction between them (F < 1). The corresponding ANOVA conducted over the training trials produced a strong effect of block, F(11, 594) = 19.96, MSE = 16,010.79, p < .0001, but no effect involving the training condition (Fs < 1).

The same pattern arose at the end of training, over the block 14. In the analysis conducted specifically over this final block there was a significant effect of sequence (322 vs. 380 ms), F(1, 54) = 131.80, MSE = 94,531.88, p < .001, whereas both the effect of condition, F(1, 54) = 3.80, MSE = 10,331.15, p = .056, and the interaction of sequence × condition, F(1, 54) = 3.40, MSE = 2,438.68, p = .07, fell just below significance. Separate analyses conducted with control and training trials showed that performance over this final block was not different between groups in responding to training trials (317 vs. 327 ms, respectively, F < 1), whereas intentional learners responded significantly slower than incidental learners to control trials (394 vs. 366 ms), F(1, 54) = 5.60, MSE = 11,404.31, p < .05.

This pattern of results, together with that found in the measure of accuracy, is highly suggestive of the explicit nature of the learning achieved by the intentional learners. Given that these learners were arguably aware not only about the existence of a predictable sequence but also about the fact that this sequence was not always respected, it appears that their explicit knowledge was not translated into faster RTs or improved levels of accuracy in response to structured trials. Instead, it provoked a higher rate of errors and slower responses to those trials that did not follow the anticipated sequence.
As for the transfer block, we expected that intentional learners could be able to show a significant amount of preserved learning in spite of the introduction of the selection task, whereas incidental learners could be expected to show a strong decline, or even an absolute removal of the learning effects, as it occurred in the transfer condition from Experiment 1. The ANOVA conducted with condition (intentional vs. incidental) and sequence (training vs. control) on the mean RTs registered over this transfer block showed no effect of condition, but it produced a significant effect of sequence, \( F(1, 54) = 9.41, \text{MSE} = 40,552.72, p < .01, \) and a significant interaction of sequence \( \times \) condition, \( F(1, 54), 4.02, \text{MSE} = 17,345.49, p < .05. \) Separate analyses conducted for each condition confirmed our predictions, by showing that the effect of sequence was clearly significant for intentional learners, \( F(1, 27) = 12.29, \text{MSE} = 55,470.93, p < .01, \) but not so for the incidental group (\( F < 1 \)).

**Generation Task**

Although participants were presented with series extracted from their training and control sequences, our interest was focused exclusively on the responses given to the training series. From these series, we computed the proportion of generation trials in which participants generated the successor corresponding to their training series, depending on whether they responded under inclusion or exclusion conditions. A large index of explicit learning would therefore be indicated by the conjunction of a large score under the inclusion conditions (larger than .50) and a small score under the exclusion task (smaller than .50).

A preliminary inspection of these scores indicated that the order in which the generation tasks had been administered turned out to produce a strong impact on these data. Therefore we conducted a mixed ANOVA using order of tests (inclusion first vs. exclusion first) and condition (incidental vs. intentional) as between-participants variables and generation instructions (inclusion vs. exclusion) as a within-participants factor. The interaction between the training conditions and generation instructions was a reliable effect, \( F(1, 52) = 4.21, \text{MSE} = .044, p < .05, \) thus showing that the scores of inclusion and exclusion differed more for intentional learners (.58 vs. .51) than for incidental ones (.51 vs. .52). However, there was also a highly significant interaction between order of tests and generation instructions, \( F(1, 52) = 81.39, \text{MSE} = .842, p < .0001, \) that could modulate the previous effect. Subsequent analyses conducted separately for each order indicated that the differences between intentional and incidental learning conditions were expressed through the generation task exclusively when the inclusion test came first. In this case, intentional learners generated according to the training series in .68 of the inclusion trials, and only on .42 of the exclusion trials, whereas the corresponding scores for incidental learners were .57 and .41, respectively. This interaction between training conditions and generation instructions was significant, \( F(1, 26) = 5.89, \text{MSE} = .038, p < .05. \) On the contrary, when the exclusion test was performed first, participants failed to properly follow these instructions and, surprisingly, they generated the successor corresponding to the training sequence more often than that corresponding to the alternative one. The means for the proportion of trials that followed the training sequence under the inclusion and exclusion conditions were, respectively, .62 and .46 for incidental learners and .60 and .49 for intentional learners. The interaction between training and generation conditions did not approach significance in this case (\( F < 1 \)).

**Discussion**

The results obtained in this experiment are highly consistent with the idea that incidental and intentional training produced
different patterns of learning, and that these two types of learning produced qualitative differences in performance, which have to do with the relative flexibility of the acquired representations. The results obtained in the generation task confirmed the existence of significant differences between intentional and incidental learners in the amount of knowledge that they can use directly to generate the most frequent successor of the series. Intentional learners were more able to discriminate between inclusion and exclusion tasks than were incidental learners, thus suggesting that they had actually developed more explicit knowledge. However, it is important to note that participants appeared to have problems understanding the nature of the cued-generation task when the exclusion instructions were presented first. Arguably, the inclusion task was easier to understand, and performing this task helped participants to cope with the demands made later by the complementary exclusion task. In contrast, presenting the exclusion task before produced an overall disorganization of performance that was extended later to the inclusion task. However, regardless of the cause of the difficulty observed in those learners who performed the exclusion task first, it is worth noting that none of the effects reported in the indirect measures of performance were modified significantly by including the order of the generation tasks as an additional factor in the analyses.

Furthermore, it is also important to note that, even in the groups of participants who performed the inclusion task first, the differences between the incidental and the intentional groups were not as large as one might have expected. From this result one might suggest that both incidental and intentional learners have acquired explicit sequence learning to some extent, given that both have shown a generation performance that is better than that expected by chance. However, it is at least as reasonable to assume that the measures from the generation tasks might not reflect exclusively explicit knowledge, but they may reflect implicit-learning effects as well. As a direct measure of learning, generation performance can arguably be taken as more sensitive to explicit learning than indirect measures of performance. Thus we may assume that if two groups differ in the measures of generation they will probably differ in the amount of explicit knowledge. However, this is not to say that all the knowledge shown through such direct measures must necessarily be attributed to an effect of explicit learning. It is precisely because no principled reason exists to establish such a mapping between processes and tasks that an approach like the one adopted in this paper, which is based on the search for qualitative differences between incidental and intentional learning, might end up being more appropriate to investigate implicit learning than one that does rely on such an a priori mapping between generation performance and explicit knowledge.

Indeed, the pattern observed in the indirect measures of performance confirmed our hypotheses concerning the existence of qualitative differences in sequence learning between two conditions that, arguably, differ mainly in the learning strategies that they foster. In the incidental condition the results replicated those obtained in the transfer group from Experiment 1, thus showing that the expression of sequence learning did not survive the inclusion of a selection task over the block 13. In the intentional learners, however, the more explicit nature of their knowledge did enable them to adapt this knowledge to the demands required by the selection task and to use it more flexibly to respond to those trials that complied with the training sequence. It is also worth noting that during the training blocks the more explicit knowledge obtained by the intentional learners did not result in faster RT in response to the training trials, but it caused these participants to commit more errors and to respond more slowly to those trials that failed to fulfill their expectations. In contrast, over the transfer block, the difference between intentional and incidental groups reflected a net benefit when the target appeared at the expected location, rather than a cost derived from its appearance at unexpected locations. These results are compatible with the idea that the explicit effects are the result of a location expectancy that may be flexibly deployed either to prepare the next response or to act as a pre-cue in the context of a search task, whereas implicit effects take the form of a more specific action program that cannot be transferred to a new context requiring a more complex task and a completely different temporal structure.

Regardless of whether the lack of transfer observed in the incidental learners has to do with the addition of a search task or with the slower pattern of responses that is forced by this new task, one might argue that the difference between incidental and intentional learners could not only be attributed to a qualitative difference between implicit and explicit learning but also to a quantitative difference in the absolute amount of learning. Indeed, our perspective is not contrary to that account, because we understand implicit and explicit knowledge as two extremes of a continuum, rather than as two entirely independent kinds of representations (Cleeremans & Jiménez, 2002). By increasing such properties as the stability, distinctiveness, or strength of a given implicit representation, we assume that the underlying knowledge may become able to produce not only stronger effects under the same conditions in which it was acquired but also a set of new and more flexible effects that render such knowledge as explicit. This more flexible knowledge could be deployed in increasingly different ways, and it could be exploited in pursuing increasingly overarching goals. As the results of this experiment do clearly illustrate, these qualitative differences in the flexibility of the acquired knowledge can be obtained even when this knowledge does not produce a between-groups difference in the amount of facilitation that it provides in response to predictable trials. The intentional application of this knowledge did not result in larger facilitation effects over the training blocks, but it produced larger costs in response to unpredictable trials and allowed intentional participants to use this knowledge more flexibly in pursuing a different goal, such as that of locating a target when it appeared surrounded by distractors over the transfer block.

In summary, the results of this series of experiments sustain the claim that explicit knowledge is not only stronger than is implicit knowledge but also endowed with emergent properties that are not present in its implicit counterparts. To counteract the claim that implicit knowledge can merely be taken as a weak form of explicit knowledge, however, it is important to investigate whether some conditions may exist that affect the expression of learning exclusively when it is explicit but not when it remains implicit. If explicit knowledge were just taken to be stronger knowledge without any new qualitative ingredient, then its effects should always be more resistant to changes than would be those derived from more implicit knowledge. In contrast, if explicit knowledge can also be defined as more flexible and more open to strategic influences, then it is likely that some manipulations might affect exclusively the expression of learning when it is explicit. For
instance, if we maintain the context over a transfer block, but
suddenly decrease the validity of the sequence, explicit learners
would be expected to notice the validity change and therefore to
adopt an attentional set directed to avoid the expression of their
no-longer valid knowledge. On the contrary, if learning remains
implicit, learners could even fail to notice the validity change and
therefore continue to use their sequence knowledge when it be-
comes applicable, even in the context of this transfer phase. The
second series of experiments were directed to empirically test this
claim.

Experiment 3

In Experiment 3 we also trained participants under incidental
and intentional instructions, in a similar way to that described for
Experiment 2. To optimize explicit reliance on the learned information,
we moved to a deterministic paradigm in which the training
sequence was repeated systematically without any interspersed
control sequence until the test blocks. We assumed that practice
with a deterministic sequence would provide enough evidence on
the structured nature of the series for the intentional learners to rely
on it. Thus we returned to a linear disposition of the stimuli instead
of using the square setting arranged in Experiment 2. To prevent
incidental learners from gaining a significant amount of explicit
knowledge from their exposition to a deterministic sequence, we
reduced the practice phase from 12 to just 6 training blocks, each
of them composed by eight repetitions of the training sequence.
Blocks 7 and 8 were used as transfer blocks, in which a control
sequence was introduced as a way to assess learning about the
training sequence. At variance with most previous studies using
this transfer setting, we did not include only control trials within
these transfer blocks, but we also interspersed a series of 12 trials
that followed the training sequence between seven repetitions of
the control series. Thus the validity of the previous knowledge
decreased over the transfer blocks from 1 to .125, but it could still
be used to improve performance in a series of 12 trials over each
transfer block. The most important question addressed by this
experiment concerned the way in which participants responded to
this repetition of the training series when it was presented in the
context of the transfer blocks. We expected that if participants in
the intentional condition learned explicitly about this training
sequence, they would notice the sudden change produced over the
transfer blocks; hence they would adopt an active strategy directed
to avoid the application of their previous knowledge. On the
contrary, if participants under the incidental condition learned the
sequence in a more implicit way, they could even fail to notice the
change produced over the transfer blocks; thus they would be
expected to keep using their knowledge whenever it becomes
applicable over these transfer blocks.

Method

Participants. Thirty-two students from the University of Granada par-
 participated in the experiment in exchange for course credits, and they were
randomly assigned to the incidental or intentional condition. They had
never participated in similar experiments before.

Procedure. The experiment was programmed using the E-Prime
(Schneider, Eschman, & Zuccolotto, 2002) software. Participants were
presented with an SRT task in which they had to respond to the location of
an asterisk appearing on each trial at one of four possible locations
displayed over the horizontal axis of a computer screen. An underline
marked the four possible locations at which the asterisk could appear, and
each of these locations was separated from the adjacent ones by 3.5 cm.
Participants responded using the keys corresponding to the letters Z, X, N,
and M on a Spanish keyboard, which were assigned to each location by
following spatially consistent mapping. The same SOC sequences de-
scribed for the previous experiments were used in this experiment either as
training or control sequences, and they were counterbalanced across par-
ticipants. All participants were first presented with an initial series of 14
trials in which the locations were completely random. After these practice
trials, they were provided with the instructions corresponding to their
specific condition. Participants in the intentional condition were warned
about the existence of a repeating sequence, and they were urged to try to
discover it and to take advantage of this structure to respond more effi-
ciently to each trial. Incidental learners were not informed about the
existence of any structure and were just told to perform the SRT task as fast
and accurately as possible.

The training phase comprised 6 blocks of 96 trials, each block featuring
eight repetitions of the training sequence. Each training block began by
randomly selecting two nonrepeated locations for the first two trials and
continued by following the rules corresponding to their training SOC over
the next trials, up to the end of the block. Blocks 7 and 8 were built as
probabilistic blocks featuring seven repetitions of the control sequence,
plus one repetition of the training sequence. The first sequence in these
transfer blocks was always a control one, after which the training sequence
could appear randomly at any point in the block. The transitions between
series were linked as described in previous experiments so that the last two
locations of each sequence could be used to predict the first location of the
following one. Block 9 was arranged as a refreshing training block, after
which participants were presented with a cued-generation task.

The generation task was slightly simplified with respect to that used in
Experiment 2. We continued to use a cued-generation task in which
participants responded to series of five trials as they did over the SRT task;
then they were told to generate the successor of this series by choosing
between two alternatives that corresponded either to the real successor of
the series or to the successor of its last two locations according to the
alternative sequence. To avoid providing new sequence information over
this generation task, we used cues from both the training and the control
sequences. At variance with Experiment 2, we presented each fragment
only once per condition so that the whole test comprised 24 series for the
inclusion conditions and another 24 series for exclusion conditions. Ex-
periment 2 had shown that the order in which inclusion and exclusion tasks
were presented constituted an important factor, and that participants per-
formed better when the inclusion instructions came first. Therefore all
participants in this experiment were tested in this order.

Results and Discussion

SRT Task. Responses corresponding to either the first two trials from each block, errors (4.5%), or latencies larger than 1,200
ms (0.8%) were discarded from the overall analyses conducted on
the measures of RT. Figure 3 represents mean RTs for the
remaining trials (plotted separately for each block) for intentional
and incidental conditions and (over the transfer blocks) separately
for control and training trials. As can be readily observed, RTs did

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2 This filter was used in Experiments 3 and 4 to minimize the influence of outliers. We decided not to use such filters in the previous experiments,
because the transfer block produced disproportionally longer latencies, and
that would have forced us to assume different filter levels for each type of
trial. This was not the case in the second series of experiments; thus we
assumed that the advantage provided by the control of outliers could
outweigh the potential dangers introduced by discarding the largest RT.
not appear to improve in a progressive way over the first six training blocks, but they suffered a considerable increase upon the administration of the transfer blocks. For the purposes of assessing sequence learning, the most relevant result concerns precisely the slowdown produced in response to control trials when they were first presented over these transfer blocks. This result resembles the typical sequence-learning effect that is reported in most deterministic sequence-learning paradigms.

A mixed ANOVA comparing the average RT to training trials from blocks 6 and 9 with RT to control trials from the transfer blocks 7 and 8, with condition (incidental vs. intentional groups) as a between-participants independent variable, showed no effect of condition (F < 1). However, it revealed a significant effect of sequence (training vs. transfer), $F(1, 30) = 74.44, MSE = 71.854.04, p < .0001$. This effect was not the result of a trade-off between speed and accuracy, because responding to the training sequence over blocks 6 and 9 was not only faster than responding to the control sequence over the transfer blocks 7 and 8 but also produced significantly smaller error rates (.05 vs. .064), $F(1, 30) = 8.99, MSE = .0003, p < .01$. All remaining Fs in the analysis of error rates were nonsignificant.

The interaction between condition and sequence was also significant in the analysis of RT, $F(1, 30) = 4.66, MSE = 4,493.17, p < .05$. The meaning of this interaction was further investigated by conducting separated analyses on the measure of RT for each condition. Both incidental and intentional learners responded significantly faster to the training trials over blocks 6 and 9 than to the control trials over the transfer blocks, $F(1, 15) = 21.17, MSE = 20,205,51, p < .001$, for the incidental group, and $F(1, 15) = 57.53, MSE = 56,141.69, p < .0001$, for the intentional group. This effect, however, was significantly larger for the intentional learners. Even though both groups produced similar RT in response to control trials over the transfer blocks (481 vs. 486 ms), intentional learners produced faster RT in response to training trials over the training blocks (402 ms) than did incidental ones (431 ms).

Of particular interest for this study was the effect of learning that could be observed specifically over the transfer blocks. If participants learned about the training sequence, then they could be expected to respond faster to those trials that comply with the sequence, even if they occurred only scarcely over the transfer blocks. However, if this learning was explicit at least for intentional learners, then these participants could be expected to notice that their previous knowledge was no longer valid over the transfer blocks; hence they could adopt a set to try to avoid its effects.

The mixed condition (incidental vs. intentional groups) × sequence (control vs. training) ANOVA performed on the data from the transfer blocks also showed a significant interaction condition × sequence, $F(1, 30) = 6.21, MSE = 14,627.83, p < .05$, but in this case the meaning of the interaction was exactly opposite to that found in the interblock analysis. Subsequent ANOVAs conducted for each condition showed that participants in the incidental condition kept responding about 35 ms faster to the training sequence trials as compared with the control sequence trials over these transfer blocks, $F(1, 15) = 17.42, MSE = 19,719.54, p < .001$, whereas this effect was completely removed for participants in the intentional group (F < 1). Actually, within these transfer blocks, participants in the intentional condition responded slightly faster (8 ms) to the control sequence trials than to the training sequence trials, but this difference was not significant.

Faced with the apparent paradox that those participants who learned more about the sequence were precisely the ones who showed lower effects of learning in the context of the transfer blocks, one may think at least about two possible accounts. First,
one may assume that participants who learned more about the training sequence also learned more explicitly about it, and hence they were more able to notice the validity change, and to undertake an explicit attempt to avoid the interference coming from these no-longer functional expectancies. Alternatively, one may claim that intentional learners may simply have performed as faster learners, who learned more quickly about both the training and the control sequences.

If this second account would turn out to be correct, we should expect that by presenting two blocks in which the previous sequence becomes extremely infrequent, whereas another sequence is made more likely, participants in the intentional condition would be led to develop new expectancies consistent with the new sequence and therefore to respond to these control trials almost as fast as they did previously to the training trials, thus decreasing the net effect of sequence learning. However, at least three sources of evidence go against this second alternative and favor the first, qualitative account. First, the interblock analyses presented previously compared the responses given to control trials over the transfer blocks with the responses given to training trials over their neighboring training blocks and showed that responses to control trials were significantly slower than those given to the training trials over the neighboring blocks. Thus despite the fact that the control trials became much more frequent over these transfer blocks, the amount of practice provided with this new sequence was not enough to produce fast responses comparable to those given over the training blocks. Second, even though Figure 3 shows a tendency for the responses given to control trials to improve with practice over blocks 7 and 8, this trend is not statistically stronger for intentional learners than for the incidental group. An ANOVA conducted on these data with block (7 and 8) and condition as independent variables showed a significant effect of block, $F(1, 30) = 14.24, MSE = 14.961.32, p < .001$, but no effect or interaction involving condition ($F < 1$). Third, a close inspection of Figure 3 shows that the main difference between intentional and incidental learners over the transfer blocks has to do with the responses given to the training trials, rather than with those given to the control trials. An analysis comparing the average RTs to the training trials over either the transfer blocks or their neighboring training blocks (6 and 9) showed a significant effect of block (training vs. transfer), $F(1, 30) = 23.46, MSE = 45,433,43, p < .0001$, as well as a significant interaction between condition and block, $F(1, 30) = 12.02, MSE = 23,272,427, p < .001$. The analysis conducted separately for each condition indicated that the intentional learners reacted significantly slower to the training trials in the context of the transfer blocks (493 ms) than in the context of the training blocks (402 ms), $F(1, 15) = 22.20, MSE = 66,869,60, p < .001$. This difference, however, was smaller (431 vs. 446 ms) and nonsignificant for the incidental group.

Together, all these results speak clearly in favor of the first, qualitative account, which assumes that, because of the explicit nature of the knowledge acquired by participants in the intentional condition, these learners noticed that the previously acquired knowledge was no longer valid over the transfer blocks and therefore adopted a discriminative set directed to avoid its influence. These strategic effects, on the contrary, would not be operative in the case of incidental learners, who would keep on performing in the same way over the transfer blocks, expressing their sequence knowledge whenever it becomes applicable in the context of these transfer blocks.

### Generation Task

To confirm that incidental and intentional learners differed in their ability to use their sequence knowledge strategically, we tested their capacity to predict the successor of fragments of their training sequence and to use this knowledge flexibly either to generate or to avoid generating the corresponding response, according to the inclusion or exclusion instructions. The ANOVA conducted over the proportion of generation responses that corresponded to the training series, with generation instructions (inclusion vs. exclusion) and condition (incidental vs. intentional) as independent variables, showed a significant effect of generation instructions, $F(1, 30) = 18.87, MSE = .353, p < .0001$, and a significant interaction between condition and generation instructions, $F(1, 30) = 5.58, MSE = .104, p < .05$. Separated analyses conducted for each group showed that intentional learners were able to discriminate between inclusion and exclusion conditions, generating the training successor in .63 of the inclusion trials and only in .40 of the exclusion trials, $F(1, 15) = 20.86, MSE = .420, p < .001$. On the contrary, this difference did not reach significance for the incidental group, which produced mean scores of .54 and .47, respectively.

As a whole, then, the direct measure from the generation task reinforced the conclusions that incidental and intentional learners differed in the amount of explicit learning that they had acquired, and that this difference may have been responsible for the qualitatively different patterns of results produced by each group in the indirect measures of performance.

A possible alternative to this account may still claim that the differences observed between these two conditions in their relative sensitivity to validity changes must not necessarily indicate the existence of emergent qualitative differences between explicit and implicit knowledge; rather they represent a quantitative difference in the amount of knowledge acquired by each group. Perhaps it is the amount of accumulated knowledge, rather than the type of knowledge acquired under intentional instructions, that produces the qualitative differences observed in Experiment 3 between incidental and intentional learners. Our final experiment was aimed at testing whether the intentional orientation to learn could be enough to produce such a difference in the strategic set, even when the amount of knowledge is approximately equated in both groups. To assess this question, we provided the intentional learners with far less training blocks and tested whether they would still be able to withhold the expression of their knowledge upon a sudden decrease in validity, or whether this control strategy would not affect performance unless a given threshold of learning is reached.

### Experiment 4

#### Method

**Participants.** Forty-eight students from the University of Granada participated in the experiment in exchange for course credits, and they were randomly assigned to the incidental or intentional condition. They had never participated in similar experiments before.
Procedure. The incidental condition was designed as a close replication of the procedure arranged in the corresponding condition from Experiment 3. The intentional condition was also a replication of the intentional condition of Experiment 3, except that participants were given just two training blocks before the introduction of the transfer blocks. All the remaining details, including the cue-generation task presented at the end of training, followed exactly the procedure described for Experiment 3.

Results and Discussion

SRT task. As in Experiment 3, the mean RTs were computed after discarding responses to the first two trials from each block, error responses (2.9%), and latencies larger than 1,200 ms (0.3%). An interblock analysis of learning was conducted by comparing the average responses to the control trials presented over the transfer blocks with the average responses to training trials presented over their neighboring blocks. The ANOVA conducted with condition (incidental vs. intentional) and sequence (control trials from the transfer blocks vs. training trials from the neighboring training blocks) produced no effect of condition (F < 1), but it showed a significant effect of sequence, F(1, 46) = 54.78, MSE = 26,283.24, p < .0001, as well as a significant interaction condition × sequence, F(1, 46) = 5.85, MSE = 2,904.90, p < .05. Again, the advantage in RT in response to the training blocks was not the result of a trade-off between speed and accuracy, because the effect of sequence was also the only significant effect observed in the ANOVA conducted over the error rates (.031 vs. .038), F(1, 46) = 4.22, MSE = .0012, p < .05. Unlike what occurred in Experiment 3, in this case the interaction between condition and sequence in the analysis of RT showed that incidental learners expressed larger effects of learning (44 ms) than did intentional learners (22 ms), arguably because the former ones had been trained three times as much as the latter ones. In any case it is important to note that the effect of learning was significant in both groups, F(1, 23) = 12.32, MSE = 5,957.93, p < .01, for the intentional group, and F(1, 23) = 48.60; MSE = 23,130.21, p < .0001, for the incidental group.

As can be observed in Figure 4, the smaller learning score obtained by the intentional learners in this analysis was not caused by the fact that they did not increase their RT in response to the control trials over the transfer blocks but rather to the fact that their RTs did not return to the previous levels of performance over the final, posttransfer block. In fact, when learning was computed alternatively by taking the difference between RT to the pretransfer block and RT to the control trials presented over the first transfer block, no significant difference arose between these two groups, F(1, 46) = 1.27, MSE = 1,043.04, p = .27. We surmise that the amount of learning obtained in these two groups could be essentially equivalent, and that the difference observed over the first comparison might be attributed to a strategic setting similar to that found over the training trials that are interspersed within the transfer blocks: explicit learners are simply more reluctant to “let them go” after having experienced two transfer blocks, and this control strategy appears to generalize to the posttransfer block.

In any case if the sensitivity to changes in the sequence validity turned out to depend on the amount of knowledge instead of on the type of knowledge determined by the instructions, we could expect one of the two following patterns of results, concerning the analysis that tests for the use of the training structure over the transfer blocks. On one hand, if we assume that the best measure of learning is the one that compares performance between the pre-
transfer and the first transfer block, then no difference should arise between groups in the way in which they respond to the training trials interspersed in the context of the transfer block. On the other hand, if we opt for the comparison between the transfer blocks and their neighboring training blocks as the best measure of the overall learning, then participants in the incidental group, which showed a larger effect, would be expected to show a stronger disposition to withhold the expression of this learning over the transfer block. Contrary to both claims, however, the comparison between RT to control and training sequence trials within the transfer blocks showed that incidental learners continued to express a significant amount of learning over this measure, whereas this did not happen in the intentional group. The corresponding ANOVA comparing RTs for training and control sequence trials over the transfer blocks showed a significant effect of sequence, \( F(1, 46) = 14.38, MSE = 4.136,96, p < .001 \), and a significant interaction condition \( \times \) sequence, \( F(1, 46) = 7.33, MSE = 2.109,53, p < .01 \). The analysis conducted for the incidental group showed a significant effect of sequence (436 vs. 458 ms), \( F(1, 23) = 16.92, MSE = 6.077,41, p < .001 \), that was not present in the intentional group (456 vs. 460 ms, \( F < 1 \)).

**Generation Task**

Previous analyses on the indirect measures of performance indicated that the instructions provided to the learners are a more direct predictor of their sensitivity to validity changes than is the amount of accumulated knowledge, at least over the range of learning tested in this experiment. Indeed, the analyses conducted on the direct measures of learning indicated that these two groups did not differ significantly in the amount of knowledge that they could flexibly use to either generate or avoid generating the successor of sequence fragments. It appears that the advantage of being trained under intentional conditions was compensated by the reduced amount of practice so that the net effect was a similar ability of both groups to explicitly use their knowledge over the generation task. The ANOVA conducted over the proportion of generation responses that corresponded to the training series, with generation instructions (inclusion vs. exclusion) and training condition (incidental vs. intentional) as independent variables, showed a significant effect of generation instructions, \( F(1, 46) = 11.11, MSE = .219, p < .01 \), but not a significant effect of condition or an interaction between them (Fs < 1).

The results of this analysis may be taken as somewhat contradictory with the claims made in the previous paragraphs, because we have been arguing that the learners’ sensitivity to validity changes depended on their explicit knowledge, but now we are acknowledging that the amount of explicit knowledge that can be used to respond to the generation task is not significantly different between these conditions. The ultimate solution to this puzzle may be difficult to achieve, but a potential starting point may be to assume that the amount of explicit knowledge that a learner can use in each different context is not always fixed; it may depend on the specific demands that each task makes on the learners’ meta-knowledge. For instance, performing the SRT task under incidental conditions makes only minimum demands on learners’ meta-knowledge; hence it may produce some learning effects that are largely independent from it. These demands become maximal when participants respond to a generation task or perform the SRT task under intentional conditions, because explicit instructions require a continuous monitoring of the learners’ expectancies. Therefore even though both groups may have acquired a similar amount of knowledge (judging both from the indirect measures of performance and from their responses to the generation task), the qualitative differences arisen in the measures of RT could be revealing that performance in the incidental condition is largely dependent on implicit influences, whereas the effects shown in the intentional group are most dependent on explicit knowledge. From our point of view, this issue may become an important issue because it suggests that qualitative differences in the orientation task can at least be as relevant as the absolute amount of acquired knowledge when determining how learning is expressed.

**General Discussion**

In these two series of experiments, we have sought to investigate the qualitative differences that can be found between incidental and intentional learning and to relate these results with a general framework that conceives implicit and explicit knowledge as two points of a representational continuum that goes from implicit to explicit cognition (Cleeremans & Jiménez, 2002). The underlying idea is that, even though implicit and explicit knowledge are parts of a continuum, emergent properties arise as an implicit representation gains strength, stability, and distinctiveness, and these emergent properties are related to the amount of control that these representations can exert, as well as to their own susceptibility to control processes. From this point of view, implicit knowledge is basically seen as a weak form of knowledge that can exert small influences if it is presented together with a number of simultaneous constraints, but that usually escapes direct control effects precisely because it is embedded in this set of constraints. In contrast, explicit knowledge is taken as a strong form of knowledge that supports metaknowledge and is affected by it, thus taking a much more direct role in driving behavior.

To assess these rather general claims, we designed two series of experiments in which learners were first presented with either incidental or intentional training conditions, and they were then presented with a transfer phase that either changed the surface of the task but maintained the regular structure or maintained the surface but changed the regular structure. In the first series of experiments, the sequence was maintained, but the task requirements were increased by embedding the SRT task in the context of a selection task that asked participants to respond to the location of a target, which was presented among several distractors. The results indicated that intentional learners gained more explicit knowledge than did incidental learners, and that only participants in the intentional conditions were able to keep using their sequence knowledge in a flexible way to anticipate the most probable location of each target over the selection task.

In the second series of experiments, we arranged a complementary setting that maintained the surface but decreased the validity of the acquired knowledge over two transfer blocks from 1 to .125. We expected that intentional learners would be able to notice the abrupt drop in validity produced over the transfer blocks, and therefore to adopt a strategic set directed to avoid relying on this knowledge. Experiments 3 and 4 confirmed these predictions by showing that, regardless of the overall amount of initial learning, participants in the intentional conditions ceased to express their
learning as soon as they were presented with the transfer blocks, whereas participants in the incidental conditions continued to respond faster to those trials that complied with the training sequence, despite the fact that this sequence had become extremely unlikely over the transfer blocks.

The picture that arises from these results is overtly consistent with the dynamic framework developed by Cleeremans and Jiménez (2002), and it provides a number of insights that may contribute to the distinction between implicit and explicit knowledge. This account has some features in common with the unitary framework put forward by Shanks (2005; Shanks & Perruchet, 2002), as well as with the episodic views defended most prominently in this context by Neal and Hesketh (1997) or by Whittlesea and colleagues (e.g., Whittlesea & Dorken, 1997; Whittlesea & Wright, 1997; Wright & Whittlesea, 1998). However, we believe that the dynamic framework also has important differences with respect to each of these alternative approaches; therefore we would like to highlight some of these differences. This framework can also be compared with theories that postulate the parallel development of implicit and explicit learning, such as those proposed by Keele and colleagues (Keele, Ivy, Mayr, Hazeltine, & Heuer, 2003) or by Willingham (1998a; Willingham & Goedert-Eschmann, 1999). We would like to end this paper by pointing out to some differences and similarities observed among all these theoretical approaches.

Instead of postulating the existence of parallel mechanisms of implicit and explicit learning, the dynamic perspective proposed by Cleeremans and Jiménez (2002) assumes that explicit learning may arise from the strengthening of implicit representations. Of course, one may assume that some forms of learning may become explicit more easily than others (perceptual learning vs. motor skill learning), or that explicit information can be supplied in form of symbolic instructions, thus surpassing the need for a direct experience. Crucially, however, this is different from assuming that, for any given content, implicit and explicit representations may be acquired in parallel, and that implicit influences would keep affecting performance even on those circumstances that hinder the expression of explicit learning (Curran & Keele, 1993; Keele et al., 2003). According to such a dual-learning theory, implicit effects would be expected to keep affecting performance in the intentional conditions of our Experiments 3 and 4, even after the changes in validity caused the strategic removal of the explicit-learning effects. In contrast with this prediction, however, we have seen that such effects were absolutely absent for the intentional groups in those experiments, and so we need to accept that explicit and implicit influences are not independent in this context: Either implicit and explicit knowledge share the same representational vehicle so that explicit knowledge grows out of prior implicit knowledge and embeds it, or the same strategic factors that controlled the expression of explicit knowledge also serve to control the expression of implicit effects. At this point, it is difficult to distinguish between these two alternatives; however, it is worth noting that other recent results show that when the sequences are learned under intentional conditions—in this case, as part of a discrete sequence production task—intentional control does remove not only explicit effects but also implicit influences (Verwey, 2003).

As for the comparison between the dynamic perspective proposed by Cleeremans and Jiménez (2002) and other unitary frame-works such as the one recently put forward by Shanks (2005) and by Shanks and Perruchet (2002), we believe that the former one endows explicit knowledge with some emergent properties that fit with the results reported in these experiments better than does the strictly quantitative account proposed by Shanks and Perruchet (2002). These authors have tried to interpret all the observed dissociations between implicit and explicit measures of learning by positing the existence of a single variable of memory strength (learning) plus some added noise that varies in a random way between different measures. According to this model, if the knowledge observed under incidental and intentional conditions were exactly of the same kind, any factor that may affect one measure of knowledge must also be expected to produce a proportional impact on the other measure.

In this set of experiments we have shown a noncontinuous pattern of effects that is difficult to reconcile with such a proportionality assumption: (1) the introduction of a selection task affects the expression of learning when the knowledge is weaker (under incidental conditions), but not when it is stronger (under intentional conditions); (2) the introduction of validity changes affect the expression of learning in the opposite way, thus showing less interference when the knowledge is weaker (under the incidental condition) than when it grows stronger (under the intentional condition); and (3) when the absolute strength of the acquired knowledge is controlled so that the intentional learners do not show any larger effects than those found in participants trained under incidental conditions, the validity changes still interfere selectively with the knowledge expressed by the intentional learners.

This noncontinuous pattern of effects can be easily managed within the dynamic framework by assuming that implicit knowledge is more context dependent, and that only when the knowledge becomes explicit does it allow for the development of relevant metaknowledge that, in turn, modulates the expression of this learning. Thus when the change produced over the transfer phase concerns merely the surface of the task, the learners’ metaknowledge will tend to favor the continued application of their knowledge despite the surface changes, whereas such surface changes could hinder the expression of learning if it remains implicit. On the contrary, when the change concerns the structural properties of the sequence, the relevant metaknowledge should favor the adoption of a strategic set directed to avoid the influence of any previous learning, whereas the context similarity with the pretransfer task would favor the continued application of such implicit learning.

As a whole, this pattern of results strongly reinforces the conclusions that qualitative differences exist between implicit and explicit knowledge, and that these differences have to do with the fact that explicit knowledge is more directly affected by strategic processes, whereas implicit knowledge is more closely tied to the details experienced over a learning episode. This view has many aspects in common with popular distinctions drawn in memory research between abstract and episodic memory (Tulving, 1983), or between data-driven versus conceptually driven processing (Jacob, 1983). Indeed, our results fit nicely with what Neal and Hesketh (1997) termed the episodic account of implicit learning, according to which the main difference between implicit- and explicit-learning tasks is that the subjects perform implicit-learning tasks by reference to prior episodes rather than to abstract
representations. We agree with this remark, which is also related to the procedural reinstatement principle put forward by Healy and colleagues in the context of skill learning (Fendrich, Gesi, Healy, & Bourne, 1995; Healy, Wohldmann, & Bourne, 2005). However, although these frameworks are generally agnostic with regard to the relation that is established between procedural and declarative knowledge, or between abstract and episodic memories, we consider that the dynamic framework can potentially offer a way to understand these relations.

The episodic view has been proposed as a functional attempt to avoid the recourse to awareness as a crucial dimension (cf. White, & Dorken, 1997). However, in our opinion, a dynamic framework such as the one described previously gives consciousness a role in understanding that episodic and abstract representations are not merely two alternative representation modes, but they are closely and productively related to each other. According to this framework, and also in agreement with other global workspace models of consciousness (Baars, 1988, 1997; Dehaene & Naccache, 2001), the construction of explicit representations is built out of the interactions produced between hosts of processing modules, some of which represent episodic information, whereas others represent the system’s momentary goals. However, the description of what counts as an episode, or the preferred level of abstraction at which declarative representations are built, do continuously change with practice and experience. Thus even though the episodic view can make a good job in accounting for most of the qualitative differences observed in these experiments between implicit and explicit learning, a dynamic framework will be needed to explain how episodes get represented, as well as why episodic and abstract representations continuously change with learning so that episodes can come to incorporate progressively more abstract information. According to this dynamic framework, one of the main functions of implicit learning may be to sustain this dynamic and to help cognitive systems to develop progressively more abstract episodes.

References


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