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Chapter 7

THE ROLE OF CUES AND STIMULUS VALENCY IN IMPLICIT TASK SEQUENCE LEARNING – A TASK SEQUENCE IS NOT ENOUGH

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ABSTRACT

Recent research has suggested that sequences of tasks can be learned implicitly. One explanation rests on the automatic activation of task sets. Alternative possibilities include perceptual learning of the sequence of task cues, or the learning of the combined correlated stream of task cues and tasks. To test these possibilities we manipulated the stimulus valency of the tasks. In Experiment 1, univalent stimuli were used and the presence/absence of instructional task cues was varied. Results showed a small but non-significant effect of task sequence learning. In Experiment 2, bivalent and trivalent stimuli were used instead of univalent stimuli and by design instructional task cues were necessary. Task sequence learning effects were found but were only significant for trivalent stimuli. Results suggest that the presence of a sequence of task cues must be attended in order to be effective.

INTRODUCTION

Predictability in an environment depends on specific relations between events and the ordering of events. The stimuli involved seldom occur purely by chance. Typically, they follow a preexisting order. Sensitivity to a structured order enables an organism to be prepared and ready for action when a particular configuration of stimuli is encountered.

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Understanding how people can be sensitive to their environment, especially without awareness, is one of the reasons why implicit sequence learning has attracted the attention of researchers (Ebbinghaus, 1902; Lashley, 1951; Nissen and Bullemer, 1987).

Recent research has shown that implicit learning of environmental structure may extend beyond sensitivity to a sequence of stimuli. For example, Koch (2001) investigated task sequence learning and suggested that learning depended on *automatic task set activation*. However, because the same stimuli were used for all the tasks, instructional cues were necessary to indicate which task to perform. By design the tasks were correlated with the sequence of instructional cues. Therefore, alternative explanations might include perceptual learning of the sequence of task cues, or the learning of the combined correlated stream of task cues and tasks. The purpose of the present study is to examine the role of cues and stimulus valency in task sequence learning. Stimulus valency refers to the number of stimulus dimensions relevant to performance of a task in a specific context.

Koch (2001) used a sequence of stimuli that each differed on three dimensions (form, colour, and size; i.e., trivalent stimuli) to test whether a task set (i.e., the intention to perform a particular task) can be activated automatically. In order for participants to know which task they needed to perform next, each stimulus was preceded by an instructional task cue. The order of appropriate left vs. right key press responses was entirely random. A sequence of nine tasks was constructed such that each possible transition between the three tasks occurred. This sequence was presented repeatedly throughout different experiments in which the length of the cue-stimulus interval and the response-cue interval were varied. Koch found implicit learning effects, notably when the response to cue interval (RCI) was short (100 vs. 900 ms), but not when the cue to stimulus interval (CSI) was long (100 vs. 900 ms). This suggests that task sequence learning depends on the co-activation and association of task cues and the stimuli required to performing the tasks.

The Role of Task Cues in Task Sequence Learning

Our first aim in the present study was to examine the contribution of task cues to task sequence learning. Therefore, we used univalent stimuli, that is, stimuli that were unambiguously associated with one specific task within a given context. This is in contrast to previous task sequence learning studies with stimuli that could be used to perform more than one task in a given context (i.e., bivalent or even trivalent). Besides Koch (2001), who used trivalent stimuli, Heuer, Schmidtke, and Kleinsorge (2001) reported task sequence learning with complex bivalent stimuli. They suggested that task sequence learning itself is unlikely to be found unless the tasks are "interpreted" in some way and they concluded that the sequences of cues were learned, but without being necessarily associated with the tasks.

In a related study, Gotler, Meiran, and Tzelgov (2003), came to a rather different conclusion about the role of task cues. They used bivalent stimuli and a task switching design, in which cues were either of the same kind throughout (constant cue condition) or were one of two kinds that occurred in random order (varied cues condition). In the latter condition, participants were instructed about both kinds of cues before the experimental blocks began and were told that they were equally valid. Gotler et al. reported evidence of implicit task sequence learning which did not differ in magnitude across the two conditions. In contrast to Heuer et al., however, Gotler et al. argued that learning must be due to the task sequence alone, "since the design prevented learning on the basis of the cue sequence" (p. 6). However, the two kinds of cue were perceptually rather similar, which has certain implications. The cues were either long arrows or fairly thick lines. Both types were shown either horizontally or vertically in order to inform the participant which binary choice dimension to respond to next. Hence, a generalized perceptual representation of the cue types was very likely to have been formed, the order of which would have correlated perfectly with the task sequence. Thus, learning might have been caused by the presence of a cue sequence or by the correlation of the cue sequence and the task sequence. One way to test this is by using univalent stimuli. It is optional whether cues are included or not with univalent stimuli, and so their contribution to implicit task sequence learning can be assessed more directly.

The Role of Univalent Stimuli

Originally, implicit sequence learning was investigated with the serial reaction time task (SRTT). Nearly all the early SRTT studies used univalent stimuli exclusively. This is because the stimuli were simple, such as asterisks at different locations, shapes and colour patches in different orders, etc. Similarly, response requirements were simple. The aim of the earlier studies was threefold. First, it was to explore the degree of complexity of sequence structure that could be learnt unintentionally, second, it was to clarify whether learning depended more on the stimulus stream or the response stream, and third, it was to establish whether resultant knowledge was actually explicit. Instructional cues were not necessary because all that the participant needed to perform the task was contained in the stimulus itself. Sequences of tasks and other forms of complex stimuli were introduced as a way of making laboratory experiments more like real world learning and to test the boundaries of implicit versus explicit knowledge.

In our previous studies (Cock and Meier, 2007; Meier and Cock, 2010) we used *univalent stimuli* without task cues but found learning effects only when a task sequence and a response sequence were correlated. If one stream was sequenced but the other was not, there were no RT changes when the sequence was surreptitiously changed to random. Even when a sequence of stimulus locations was combined with either a task sequence or a response sequence (Meier and Cock, 2010), implicit sequence learning was only observed when two correlated streams of information were present (i.e., a task sequence and a response sequence, a location sequence and a task sequence, or a location sequence and a response sequence). Moreover, Weiermann, Cock, and Meier (2010) showed that sequence learning in the paradigm introduced by Heuer et al. (2001) occurred only when the sequence of tasks and the sequence of task-to-response-mappings were correlated, but not when only one sequenced stream was present. We concluded that, with univalent stimuli, the mere presence of a sequenced order amongst the tasks is not sufficient for implicit task sequence learning to occur (Meier and Cock, 2010). We proposed that the presence of at least two correlated streams of information is at the core of implicit sequence learning and suggested that the information in each stream can be of any kind. However, in these previous studies we did not systematically examine the role of stimulus valency or the role of instructional task cues.

The Role of Bivalent Stimuli

Our second aim in the present study was to extend the findings of Koch (2001). It should be noted here that the task sequence learning studies that have used bivalent rather than univalent stimuli are rooted in the domain of *task-switching* rather than *sequence learning*. Hence, Koch (2001) was mainly interested in potential differences between "task switch" and "task repeat" trials and the manipulation of RCI and CSI. In our present experiments, however, we focus on the role of *task cues* and *stimulus valency* in sequence learning specifically. We anticipated that bivalent, as well as trivalent, task cues would play a positive role in the learning effects. As noted above, these stimuli have properties relevant to more than one task, hence participants have to be given instructional cues, and, as a consequence, a sequence of cues also exists in the materials, which invariably correlates with the sequence of tasks. We have conjectured, therefore, that the task sequence learning effects that have been found in studies using bivalent stimuli might be attributable to the combined learning of the task sequence (i.e., automatic task-set activation) and the instructional cue sequence (i.e., perceptual sequence learning).

Koch (2001) concluded that learning of the cue types led to pre-activation of the task sets, referring to it as "an abstract sequence of perceptual stimulus dimensions" (p. 1483). He suggested that "if the cues are learned, then it is highly probable that the cue also activates the task set associated with it" (p. 1484). In other words, Koch seemed to favour an active and integrative kind of learning that links the sequence of task cues and the sequence of tasks. Furthermore, this account fits well with our argument that correlated streams of information lie at the core of implicit sequence learning (Cock and Meier, 2007, Meier and Cock, 2010, Weiermann et al., 2010). Our goal was thus to merge the two approaches.

EXPERIMENT 1

Experiment 1 was conducted to ascertain whether, using a task sequence learning paradigm, implicit learning effects could be found with instructional task cues and *univalent stimuli*. In our previous study, using *univalent stimuli* without instructional task cues, we found sequence learning effects but only when the task sequence was correlated with a binary choice response sequence of the same length (Cock and Meier, 2007). When combined with a random order of stimuli and a random order of binary choice responses, the task sequence showed no learning effects. We hypothesized that task sequence learning in this situation might benefit from the presence of instructional task cues. Our reasoning was that the stream of cues would introduce a perceptual ordering that would support task set activation. In order to test this hypothesis we used a slightly modified version of the paradigm of Koch (2001).

Method

Participants and Design

Forty undergraduate students from the University of Bern participated in return for course credit (23 women and 17 men, mean age 25 years, age range 22 to 32 years). They were assigned at random to one of two experimental conditions. Condition (*with* and *without task cues*) was manipulated between subjects, whilst block was manipulated within subjects, resulting in a mixed design.

Materials

Stimuli were approximately 4 cm x 3 cm in size and displayed one at a time against a white background using E-Prime 1.1 software (Psychology Software Tools, www.pstnet.com). A letter task comprised one of six letters (h, l, r, H, L, R) shown in black and an upper vs. lowercase decision, a shape task comprised one of six geometric shapes (circle, horizontal oval, vertical oval, square, horizontal rectangle, vertical rectangle) shown in black and a curved vs. angular decision, a colour task comprised one of six fuzzy figures (three presented in red and three in blue) and a red vs. blue decision. The three task dimensions were therefore mutually exclusive and all 18 stimuli were *univalent*. In both conditions the randomly ordered stimuli occurred equally often. There were no consecutively repeated stimulus transitions between trials and no repeated stimulus transitions in the same block. In other words, there was no complete or even partially repeated stimulus sequence. As in the study by Koch (2001), the only sequenced order was that of the tasks in conjunction with the task cues.

In both conditions, task order was sequenced across the blocks of trials, and in a counterbalanced way relative to a sequence changeover at block 9 (interference block). The two statistically identical nine element task sequences were "*letter colour shape shape letter letter shape colour colour*" and "*letter shape colour colour shape shape letter letter colour*". At any point in the sequence cycle, the correct order of at least two preceding tasks would need to be known in order to correctly predict the next task (i.e., second order sequencing). In both conditions left (L) and right (R) key press responses followed a pseudorandom order, with the restriction of no L or R runs in excess of 3 consecutive trials. The overall numbers of L and R responses were equal per block.

In one condition, external cues were presented at the four corners of each stimulus display. Three small "xxx" (1 cm x 0.5 cm) were shown for a letter task, a square inside a circle (1.3 cm x 1.3 cm) for a shape task, and a yellow "&" (1.5 cm x 1.5 cm) for a colour task. Stimulus and cue displays were centrally presented in 14 point Courier New font with a viewing distance of approximately 40 cm. The same two response keys were used for all three tasks.

Procedure

Participants were tested individually in a quiet room, with instructions given on paper and summarized on the computer screen. They were told that the experiment concerned the effects of practice on response speed. The three tasks were explained and participants were instructed to use their L or R index fingers to make responses. For a colour task, they had to decide as quickly as possible whether the stimulus was red or blue and press the appropriate response key (L for red and R for blue). For a shape task, they had to decide whether the stimulus was curved or angular and press the appropriate response key (L for curved and R for angular), and for a letter task, they had to decide whether the stimulus was a lower or uppercase letter and press the appropriate response key (L for lowercase and R for uppercase). Participants in the condition with task cues were advised that shortly before the appearance of each stimulus display, cues would appear on screen, telling them which task to perform next. Examples of the cues were shown on an instruction page, as well as on screen at the start of the experiment. Participants were told to respond as accurately and quickly as possible, and that if they made mistakes, they should simply continue. Participants were familiarized with the stimulus to response mappings (S-R) during an initial practice block. To assist them, there was a small panel at the edge of the screen indicating which response (L or R) was appropriate for each task outcome.

Each trial began with a blank screen for 100 ms, followed by a rectangular frame and a task cue. The cue appeared on screen 100 ms before the stimulus (cue-stimulus interval, CSI) and remained present until a response was made. There was an interval of 100 ms (response-cue interval, RCI) before presentation of the next cue.

A block consisted of 72 trials. The initial practice block was followed by eight experimental blocks, by one interference block (Block 9, comprising 72 trials of the alternative sequence) and by a final experimental block. There was a brief pause between each block. No feedback on performance was provided. After the test session, which lasted approximately 30 to 40 minutes, a structured interview was conducted. Participants were asked if they had noticed anything in particular about the order of the tasks. The existence of sequences was explained, and participants were then asked to report the nine element sequence they had received, either by guessing or from memory.

Data Analysis

Trials on which errors were made, and the first trial after each error, were excluded from analysis. Error rates were averaged over all blocks of trials and all three tasks. For each block, the first nine element cycle of the sequence was excluded from analysis. Following the procedure of Koch (2001), responses with a latency of more than 1,500 ms were discarded (3%). Error rates were generally low (on average 5%) and are not presented further.

Response time (RT) data for the various tasks were aggregated and mean RTs per block were computed separately for each participant. *Training scores* were calculated as the RT difference between blocks 3 and 7. Decreasing RTs were taken as directly indicative of a general training effect (possibly also including a sequence learning effect). *Interference scores* were calculated as the mean RT difference between block 9 and the average of surrounding blocks 8 and 10. Increased RTs at block 9 (alternative sequence) were taken as indirectly indicative of prior learning of the main sequence. An alpha level of .05 was used for the analyses. Degrees of freedom and *MSE* values were Greenhouse-Geisser adjusted where appropriate. Effect sizes are expressed as partial η^2.

Results

The RT results decreased initially for both conditions (see Figure 1 bottom). *Mean training scores* (block 3 minus block 7) were 44 ms (SE = 11) for the condition *without task cues* and 38 ms (SE = 12) for the condition *with task cues*. A mixed two factorial ANOVA, with RTs at blocks 3 to 7 as a within subjects factor and condition as a between subjects factor, revealed a significant main effect of block, $F(4, 152) = 10.65$, $MSE = 947$, $p <. 01$, $\eta^2 = .22$, but no effect of condition, $F(1, 38) = .63$, $MSE = 67{,}337$, $p = .43$, $\eta^2 = .02$, and no interaction, $F(4, 152) = .12$, $p = .98$, $\eta^2 = .003$.

Mean *interference scores* (RTs at block 9 minus the average of blocks 8 and 10) were 2 ms (SE = 7) for the condition *without task cues* and 6 ms (SE = 6) for the condition *with task cues* (see Figure 2).

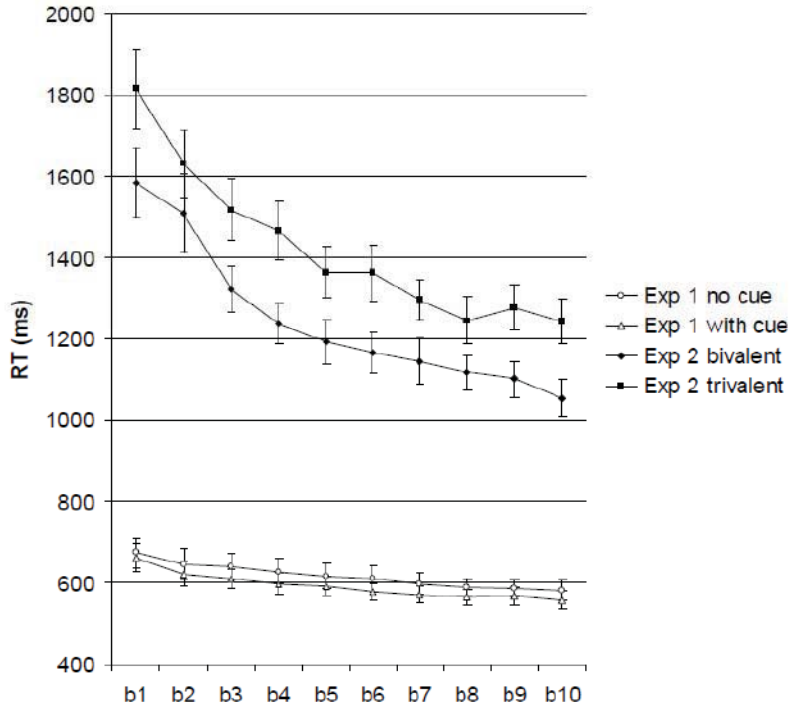

Figure 1. Mean response times for Experiment 1 (lower lines) and Experiment 2 (upper lines). Error bars represent standard errors.

A mixed two factorial ANOVA was used at compare performance between the two conditions, with RTs at block 9 compared to the average of blocks 8 and 10 as a within subjects factor and condition as a between subjects factor. This revealed no main effect of block, $F(1, 38) = .73$, $MSE = 416$, $p = .39$, $\eta^2 = .02$, no effect of condition, $F(1, 38) = .51$, $MSE = 7{,}583$, $p = .48$, $\eta^2 = .01$, and no interaction, $F(1, 38) = .23$, $p = .64$, $\eta^2 = .01$. The result of a planned one-tailed *t*-test against an *interference score of zero* did not reach significance for either condition, $t(19) = 1.01$, $p = .16$, *with task cues*, and $t(19) = .25$, $p = .40$, *without task cues*.

Explicit knowledge. Three participants in the condition *without task cues,* correctly reported six of the nine task sequence elements they had received (mean *interference scores* = -15 ms, 48 ms and 30 ms). The average level of explicit knowledge (EK) for this condition was 4.20 (*SE* = .30) elements correct. None of the participants in the condition *with task cues* correctly reported as many as six elements. The average EK level for this condition was 3.55 (*SE* = .20) elements correct.

Conclusion

In Experiment 1, univalent stimuli were used and the presence/absence of instructional task cues was varied. We anticipated that a stream of instructional cues would introduce a perceptual ordering which would support and facilitate incidental task sequence learning through automatic *task set activation.* The results showed only a very small, non significant task sequence learning effect (mean RT *interference score* of 2 ms *without task cues* compared to 6 ms *with task cues*). Our tentative, and admittedly speculative, explanation is that the presence of the stream of instructional cues was not sufficient to activate task sequence learning. Although the cue sequence correlated perfectly with the task sequence, which according to our earlier study (Cock and Meier, 2007) ought to induce task sequence learning, attention to the cues was not essential for performance. In fact, it was more economic to ignore them. Attending to the cues could have distracted participants from making rapid responses as required. We think this is an important finding as it suggests that whilst correlated streams of information might indeed be necessary for implicit task sequence learning, they may be insufficient without task set relevance. By task set relevance we mean that properties of the tasks, such as cues, must be actively processed.

EXPERIMENT 2

Experiment 2 was conducted to ascertain whether, using the task sequence learning paradigm as in Experiment 1, stronger implicit learning effects would be found with *instructional task cues* and either *bivalent* or *trivalent stimuli.* This arrangement was essentially a further extension of the study by Koch (2001). It was anticipated that these kinds of stimuli would be more likely, than univalent stimuli, to activate the separate task sets because they should oblige participants to use the cues.

Method

Participants and Design

Forty undergraduate students from the University of Bern participated in return for course credit (24 women and 16 men, mean age 25 years, age range 17 to 33 years) and were assigned at random to one of two experimental conditions. Stimulus condition (*bivalent or trivalent*) was manipulated between subjects. Block was manipulated within subjects, resulting in a mixed design as in Experiment 1.

Materials

Bivalent stimuli were created by presenting six different letters and six different geometrical shapes, identical to those used in Experiment 1 as univalent stimuli, but coloured red or blue instead of black. Task cues indicated which dimension needed to be attended on each trial. Trivalent stimuli were created by presenting one out of only two particular letters. The two letters differed according to case ("B" or "K", "b" or "k"), colour (red or blue) and shape (curved or angular). Again, task cues indicated the relevant dimension.

Procedure and Data Analysis

These were identical to those in Experiment 1.

Results

The RT results decreased initially for both conditions (see Figure 1 top). *Mean training scores* were 179 ms (*SE* = 31) for the condition with *bivalent stimuli* and 222 ms (*SE* = 42) for the condition with *trivalent stimuli*. A mixed two factorial ANOVA , with RTs at blocks 3 to 7 as a within subjects factor and condition as a between subjects factor, revealed a significant main effect of block, F (4, 152) = 26.08, MSE = 9689, $p < .01$, $\eta^2 = .41$, a significant main effect of condition, F (1, 38) = 5.43, MSE = 328217, $p < .025$, $\eta^2 = .13$, but no interaction, F (4, 152) = .93, $p = .45$, $\eta^2 = .02$.

Mean *interference scores* were 16 ms (SE = 23) for the condition with *bivalent stimuli* and 32 ms (SE = 18) for the condition with *trivalent stimuli* (see Figure 2). A mixed two factorial ANOVA with RTs at block 9 compared to the average of blocks 8 and 10 as a within-subjects factor and condition as a between-subjects factor revealed neither a main effect of group, F (1, 38) = 2.82, MSE = 4145, $p = .10$, $\eta^2 = .07$, nor of condition, F (1, 38) = 5.94, MSE = 94917, $p = .20$, $\eta^2 = .14$ and no interaction, F (1, 38) = .35, $p = .56$, $\eta^2 = .01$.

While a planned comparison of the *interference score* against zero failed to reach significance for the condition with *bivalent stimuli,* t(19) = .70, p = .25, the comparison revealed a significant learning effect in the condition with *trivalent stimuli,* t(19) = 1.87, p = .04.

Explicit knowledge. One participant in the condition with *bivalent stimuli* correctly reported eight of the nine task sequence elements she had received (*interference score* = 191 ms). The average EK level for this condition was 3.85 (SE = .28) elements correct. One participant in the condition with *trivalent stimuli* correctly reported eight elements of the nine element task sequence and another correctly reported six elements (*interference scores* 149 ms and 16 ms, respectively). The average EK level for this condition was 4.10 (SE = .30) elements correct.

Conclusion

In Experiment 2, we hypothesized that implicit task sequence learning effects would be found in both groups. Although only the *trivalent stimuli* condition reached statistical significance, the *bivalent stimuli* condition showed a trend in the expected direction and we imagine that running the experiment with a larger number of participants should result in a significant effect.

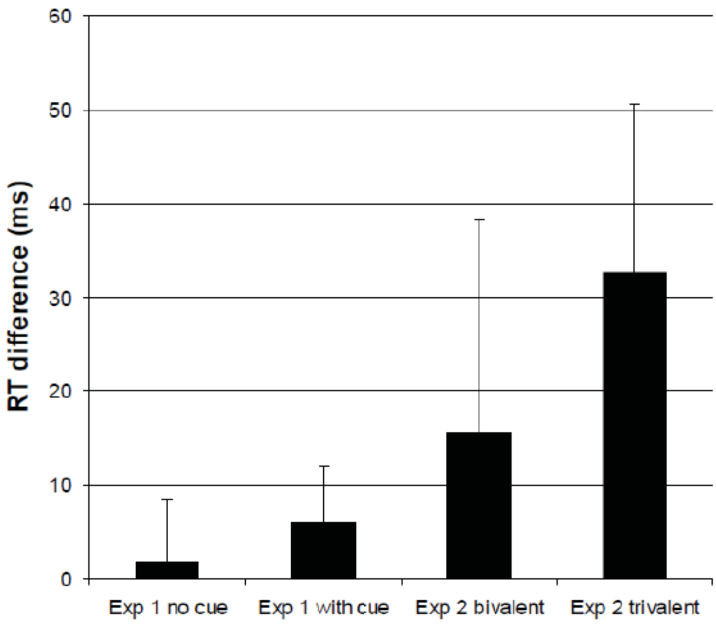

Figure 2. Interference scores in terms of mean difference in response time at random block 9 compared to surrounding sequenced blocks 8 and 10 for Experiments 1 and 2. Error bars represent standard errors.

With regard to response times in general, participants in the *trivalent stimuli* condition performed more slowly than in the *bivalent stimuli* condition, by about 200 ms throughout the experiment.

It suggests that this group took more time and perhaps made more effort in preparing for each upcoming task. It seems possible that these participants learned more about the task sequence by using the cue sequence more systematically, resulting in a somewhat larger mean *interference score.*

GENERAL CONCLUSION

Across the two experiments, we observed that with more complexity in the stimuli larger task sequence learning effects emerged. This ran from a 2 ms mean interference score on the random block for the condition univalent stimuli without cues, to 6 ms for univalent stimuli with cues, to 16 ms for bivalent stimuli with cues, and finally, to 33 ms for trivalent stimuli with cues (see Figure 2). The gradual increase suggests that learning does not simply happen in a passive way through the existence of structure in the materials. Rather, it seems that certain aspects of the underlying structure are engaged, or activated, by the more demanding task requirements. Among others, Wright and Whittlesea (1998) made a similar point. In a series of implicit learning experiments, they demonstrated that what participants learn depends very much on how the structural components of the materials are organized. They argued that implicit learning is very much an active rather than passive process. This implies that attentional requirements and relevance of stimulus features might play an important role.

Even so, the role of attention in implicit sequence learning is far from clear. *Selective attention* to different aspects of streams of information can improve or impair sequence learning, or have no effect at all (Jimenez and Mendez, 1999; Riedel and Burton, 2006). For example, in one of their experiments Jimenez and Mendez (1999) used the traditional SRTT where participants had to respond to stimulus locations. Additionally, the stimuli were of various shapes and the shape of the current stimulus predicted the following location. This relation was found to influence implicit learning, but only when stimulus shape was attended to in a selective way. Similarly, in an experiment by Riedel and Burton (2006), participants listened to lists of different colour words, each word being spoken by a different speaker. Words were presented such that speaker identity followed one sequence and spoken colour followed another. Riedel and Burton found implicit sequence learning, but only when each separate sequence was processed under selective attention.

Similarly, some studies have shown a detrimental effect of *divided attention* (Nissen and Bullemer, 1987; Shanks and Channon, 2002), whilst others have shown that, depending on sequence structure, adding a secondary task can have little or no impact (Cohen, Ivry, and Keele, 1990; Jimenez and Mendez, 1999; Reed and Johnson, 1994). The answer may lie in the degree to which a secondary task can be successfully incorporated into carrying out sequence learning requirements (Stadler, 1995, Shanks, Rowland, and Ranger, 2005; Schmidtke and Heuer, 1997). Stadler, for example, found that the disrupting effect of tone-counting was not due to a reduction in attentional resources. Rather, the random structure of the tone-counting task interfered with the regular structure of the sequence that was being learned. In contrast, in a separate experiment, Stadler showed that sequence learning was not disrupted by a secondary memory-for-letters task which needed attention but did not interrupt the temporal flow of the sequence learning.

Overall, the message from these studies seems to be that task requirements, as well as type of material and structure of design, contribute to implicit sequence learning and that the role of attention depends on the precise circumstances. With regard to our present experiments, and others like them, we suggest that stimulus valency and the presence of instructional cues can also play a role in determining what is learned in an SRTT. Importantly, their contribution would appear to be closely linked to redundancy as well as task relevance. For example, in Experiment 1, although cues were present and positively related to the tasks, it was not vital to process them in order to perform the task requirements. They could be selectively ignored, and hence they did not enhance learning. In contrast, in Experiment 2, the changing stimulus dimensions (bivalent and trivalent) needed to be selectively attended. Hence, task cues were processed in conjunction with sequence learning and were apparently beneficial.

Another open question is whether task set activation is possible without instructional cues. In our previous study (Cock and Meier, 2007), which had only univalent stimuli and no instructional task cues, we achieved a learning effect when the sequence of tasks was correlated with a sequence of L vs. R key press responses. One possibility is that each key press simply activated the subsequent task set. However, this is unlikely because despite being the same length, the task sequence and the response sequence were not isomorphic. The separate components of one stream did not predict the components of the other. More importantly, owing to the correlation, a sequence of perceptual stimulus categories also existed - in that condition exclusively. We suggested that this perceptual sequence, in conjunction with the sequences of tasks and of responses, and *not* the task sequence itself, was learned. In Experiment 2 of the present study, however, it would seem to be the existence of the stream of instructional task cues together with the task requirements themselves that facilitates task sequence learning. More complexity in the stimuli may necessitate selective attention to the changing dimensions. Furthermore, the sequence of cues and the sequence of tasks are correlated. We think that a task set activation explanation depends on this active and integrative merging of the two streams.

Finally, we have suggested that correlated streams of information may be at the core of implicit learning (Meier and Cock, 2010). The message learned from the present study is that the mere presence of correlated streams of information is not sufficient. Active or attentive processing of each of these streams seems to be necessary as well.

AUTHOR NOTE

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