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Effects of Mood on Learning in the Serial Reaction Time Task

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Preface

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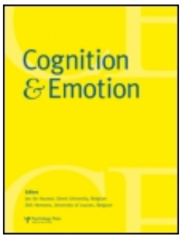

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Effects of Mood on Learning in the Serial Reaction Time Task

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Abstract

After a brief overview of existing research on the relationship between mood and implicit learning, some methodological concerns are addressed and an empirical study is reported. Participants (N = 80) were trained on a serial reaction time (SRT) task. Mood was induced by the target stimuli being pictures of human faces expressing happiness (*positive* mood condition) or sadness (*negative* mood condition). Response stimulus interval (RSI) was 0 or 500 ms, traditionally associated with implicit and explicit learning, respectively. Results showed a significant interaction between mood and RSI on the amount of learning: At RSI-500 there was a trend for negative mood to facilitate learning. At RSI-0 mood did not influence learning. Mood also influenced performance on a subsequent generation task. Results are discussed in relationship to theoretical models of the interplay between mood and cognition, as well as to existing, contradictory evidence on the effect of mood on implicit learning.

Keywords: Implicit learning; Serial reaction time task; Sequence learning; Mood; Individual differences

Sammendrag

Etter en kort gjennomgang av eksisterende forskning på forholdet mellom stemningsleie og implisitt læring, vil en del metodologiske betraktninger trekkes frem og en empirisk studie rapporteres. Forsøkspersoner (N=80) gjennomførte en sekvenslæringsoppgave (SRT). Stemningsleie ble indusert ved å benytte stimuli som var bilder av menneskelige ansikt som uttrykte glede (positivt stemningsleie-betingelse) eller tristhet (negativt stemningsleie-betingelse). Respons stimulus intervall (RSI) var 0 eller 500 ms, tradisjonelt forbundet med henholdsvis implisitt og eksplisitt læring. Resultatene viste signifikant interaksjon mellom stemningsleie og RSI på mengden læring: Ved RSI var det en trend for at negativt stemningsleie fremmet læring. Ved RSI-0 var det ingen effekt av stemningsleie på læring. Stemningsleie påvirket også prestasjon på påfølgende generasjonsoppgave. Resultatene diskuteres i henhold til teoretiske tilnærminger til samspillet mellom stemningsleie og kognisjon, samt eksisterende og motstridende forskningsresultater på relasjonen mellom stemningsleie og implisitt læring.

Effects of Mood on Learning in the Serial Reaction Time Task

The concept of implicit learning refers to learning of complex relations in the environment that influences an individual's behaviour and choices, without the person being fully conscious of the product and/or process of learning. According to Reber, "knowledge acquired from implicit learning procedures is knowledge that, in some raw fashion, is always ahead of the capability of its possessor to explicate it" (Reber, 1989, p. 229). As Reber underlined, implicit learning occurs largely unintentionally, attempts at verbalizing the knowledge is often difficult or impossible, and the individual is not necessarily aware of the details of the acquired knowledge. Although there is considerable and continuing controversy around the exact nature of the mechanisms involved in implicit learning, substantial evidence supports that a great degree of our knowledge is acquired incidentally and unintentionally (Cleeremans, 1993).

Implicit learning is posited to play an important role within different areas of human functioning, including interpretation of social signals (Lieberman, 2000), learning of social predictions (Heerey & Velani, 2010) and learning of grammatical rules of the native tongue (Reber, 1967).

Over the last decades several experimental procedures have been developed to study implicit learning in the laboratory. The two most common procedures are the artificial grammar learning (AGL) task (Dienes, Altmann, Kwan, & Goode, 1995; Reber, 1967), and a sequence learning task referred to as the serial reaction time (SRT) task (Destrebecqz & Cleeremans, 2001; Nissen & Bullemer, 1987). In the training phase of an AGL task (Reber, 1967) participants are exposed to numerous letter strings, which unbeknown to them, are structured according to a finite-state grammar that determines the selection and order of letters. In the test phase participants' ability to distinguish between strings following the grammar and strings that violate it is measured by their ability to accurately classify a series of novel letter strings according to grammaticality. Learning is measured by means of classification accuracy, whereas conscious awareness of grammar knowledge is measured by confidence ratings (Dienes, et al., 1995) and self-reported decision strategy (Dienes & Scott, 2005). In the SRT task (Nissen & Bullemer, 1987) participants learn to respond fast in relation to a visual stimulus that moves between positions on a computer screen according to a complex sequential structure. In the training phase of an SRT task, the task is to indicate the position of the target stimulus as fast and as accurately as possible by making a series of fast key press responses. Unbeknown to participants the order of stimulus positions follows a deterministic or probabilistic sequence. Sequence learning is primarily indicated by the relative difference in reaction time (RT) between trials/blocks where the target follows the sequence and trials/blocks where the sequence is violated. Conscious awareness is measured by different forms of recognition and generation tasks, where participants have to actively apply their acquired knowledge. A less common method for studying implicit learning is detection of hidden covariance (HCD) task (e.g. Hill, Lewicki, Czyzewska, & Schuller, 1990; Lewicki, Hill, & Czyzewska, 1997). In the training phase of an HCD task participants are presented with a series of stimuli, which are accompanied by some other feature or stimuli, and told to pay close attention to both stimuli. For instance, a set of facial stimuli can be accompanied by personal information, e.g. test scores for each person portrayed. In the test phase participants are presented with a series of novel stimuli (e.g. facial stimuli) and are asked to predict some other feature or stimuli (e.g. personal information, test scores). Learning is measured as the extent to which participants' predictions are consistent with the covariance presented in the training phase. Conscious awareness is typically measured by some form of post-experimental interview, where participants are asked whether they based their ratings on any specific criteria or used a specific strategy to form their judgments (Hill, et al., 1990).

Implicit Learning and Individual Differences

From an evolutionary perspective, Reber (1989) argues that there should be less individual variation in the ability to acquire knowledge implicitly than explicitly. More specifically, one should expect to find less individual differences in tasks involving implicit learning than tasks involving explicit learning, as implicit learning is assumed to depend on evolutionary older structures and processes (Reber, 1989). This assumption is in line with the findings reported from a study by Reber, Walkenfeld and Hernstad (1991), which explored individual differences in explicit versus implicit learning, as measured by a series-completion problem-solving task and a standard AGL task, respectively. Reber et al. (1991) reported substantial differences on the explicit task, but not on the implicit task.

However, a number of recent studies have challenged this view by showing evidence of individual differences in implicit learning ranging from aspects of psychometric intelligence (Kaufman et al., 2010) to personality factors (Norman, Price, & Duff, 2006; Woolhouse & Bayne, 2000). More specifically, Kaufman et al. (2010) found that implicit learning as measured by an SRT task was related to a number of individual difference variables, including verbal analogical reasoning and processing speed aspects of psychometric intelligence, performance on two foreign language exams, as well as intuition, openness to experience and impulsivity. Consistent with this, Norman et al. (2006) reported a relationship between implicit learning and the openness to feelings subscale of NEO-PI-R on an SRT task. Applying a different experimental procedure, Woolhouse and Bayne (2000) found a relationship between cognitive intuitive style, as measured by MBTI, and performance on a HCD task.

Implicit Learning and Mood

The topic of the current paper is to explore whether and how performance on an implicit learning task is affected by mood, which could be considered another individual difference variable. Mood can be defined as "relatively low-intensity, diffuse and enduring affective states that have no salient antecedent cause and therefore little cognitive content" (Forgas, 2001, p. 15). The notion that positive and negative mood conduce qualitatively different forms of information processing is pervasive within current theories about the relationship between mood and cognition. This is consistent with an early understanding of mood as "barometer of the ego state" (Jacobsen, 1957 p. 75) referring to the influence of mood throughout the entire state of the ego, including specific qualities of thinking. Numerous studies have addressed the effect of mood on cognitive mechanisms involved in explicit cognition, for example by investigating the interaction of cognition and emotion in relation to depression, revealing cognitive impairments ranging from biases in interpretation and memory to biases in attention (e.g. Eizenman et al., 2003; Gotlib & Joormann, 2010; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Kizilbash, Vanderploeg, & Curtiss, 2002; Lawson & MacLeod, 1999; Matthews & MacLeod, 2005). Research on psychopathology related to elevated mood, i.e., manic cognition, seems to mirror some of the cognitive effects of depression, including a complementary effect of broadening the scope of attention (Fredrickson & Branigan, 2003; Murphy et al., 1999). In contrast, there is much less empirical evidence of a relationship between mood and implicit cognitive processes, as those involved in implicit learning, which is the focus of the current paper. Increased knowledge about the relationship between mood and implicit learning has important implications in light of the assumed part implicit learning plays in social perception and decision-making.

Reber's (1989) argument to view implicit learning processes within an evolutionary context was initially tested by investigating whether implicit learning was robust in the face of psychiatric disorders. More specifically, Abrams and Reber (1988) argue that whereas the more recently evolved systems and processes involved in explicit learning are likely to suffer dysfunctions under conditions of psychopathology, for instance mood disorders, the more primitive systems involved in implicit learning would be more resilient under such conditions. Given what is known about the relationship between mood and cognitive processes (e.g. Bless & Fiedler, 2006; Bohner & Weinerth, 2001; Eizenman, et al., 2003; Fredrickson & Branigan, 2003; Gotlib & Joormann, 2010; Gotlib, et al., 2004; Matthews & MacLeod, 2005), it could be predicted that neither negative nor positive mood would have any substantial effect on implicit learning even though it may affect explicit learning.

The predictions inferred from Abrams and Reber's model can be supplemented by predictions inferred from other theoretical approaches concerning the effect of mood on information processing. According to a *global versus local processing* perspective negative mood promotes a more local, detail-oriented processing of the stimuli whereas positive mood promotes more global processing strategies (e.g. Basso, Schefft, Ris, & Dember, 1996; Bless & Fiedler, 2006; Bohner & Weinerth, 2001; Curby, Johnson, & Tyson, 2011; Gasper & Clore, 2002). Assuming that implicit learning does not involve a local, systematic, analytical form of processing, a global versus local processing perspective would therefore predict a beneficial effect of positive mood on implicit learning by promoting more global processing strategies as opposed to local, systematic and analytical processing strategies. This is evident from research on emotion and intuitive /automatized decision-making. For example it has been shown that a positive mood leads to better performance, whereas negative mood leads to impaired performance compared to neutral mood, on a task involving implicit judgments of semantic coherence (Bolte, Goschke, & Kuhl, 2003).

Although the *mood-as-information* (Schwarz, 1990) and *hedonic contingency* (Wegener, Petty, & Smith, 1995) approaches assume different mechanisms involved in the effect of mood on cognition, they would both predict a positive mood to involve less effortful processing and thereby be associated with reduced performance on tasks that to some degree involves effortful processing. To the extent that implicit learning benefits from the absence of a conscious effortful intention to learn, it follows that these approaches would therefore predict a beneficial effect of positive mood on implicit learning.

According to the mood-as-information approach, a positive mood will inform individuals of a safe environment, which reduces their motivation to elaborate information in that environment, thus leading to less effortful processing with increasing use of heuristics. In contrast, a negative mood signals that the current situation is problematic and individuals are more likely to use effortful, detail-oriented and analytical processing strategies (Schwarz, 1990). The mood-as-information approach is an important contribution to explaining why a negative mood is sometimes beneficial to performance on tasks that require analytical, systematic and detail-oriented processing and sometimes is detrimental to performance on tasks that require a more holistic and creative approach. Given that implicit learning does not involve analytical, systematic and detail-oriented processing, it can thus be predicted that positive mood would beneficial. Conversely, a negative mood would be beneficial if implicit learning did involve such analytical, systematic and detail-oriented processing.

The hedonic contingency approach involves a further elaboration of the effect of positive mood. It is argued that positive mood may lead to a tendency to avoid careful information elaboration as it potentially may change the positive emotional state, whereas a negative mood may promote effortful processing in attempts at changing the negative emotional state (Wegener, et al., 1995). Whether positive mood in fact leads to an avoidance of careful information elaboration is however contingent on the hedonic consequences of the task, whereby a positive mood may promote systematic thinking if it is believed to maintain the positive mood.

In the following, the empirical evidence of the effect of mood on implicit learning will be reviewed, evidence that to date is rather limited, and largely contradictory.

Patient studies. One line of the research consists of empirical studies of clinical populations, mainly investigating the effect of depression on implicit learning. Some of these studies have found implicit learning to be unaffected by depression. One example is Abrams and Reber's (1988) study, which looked at performance of a group of psychiatric inpatients, primarily diagnosed with disorders such as major depression, schizophrenia and chronic alcoholism, on an implicit learning task and on an explicit learning task. Performance was compared with that of a control group consisting of college students. The results on the explicit learning task, as measured by a simple arithmetic task, revealed significant differences between the groups, with controls significantly outperforming the psychiatric group. In contrast, performance on the implicit learning task, as measured by a standard AGL task, did not differ across the two groups (Abrams & Reber, 1988). Hence, the results were taken in favour of the hypothesis of robustness of implicit learning compared to explicit learning. In accordance with the recent focus on whether reported cognitive deficits in memory and learning are still present after remission of clinical symptoms of depression, a study by Pedersen et al., (2010) explored performance on both explicit and implicit learning tasks in recently remitted depressed inpatients. The study revealed that the recently remitted inpatients with depression showed no impairment on either explicit or implicit learning, using a serial generation task and an SRT task, respectively. However, in the group of recently remitted inpatients, explicit learning was negatively correlated with their depression score on the Beck Depression Inventory (Pedersen et al., 2009). With a different approach, using measurements of depression to distinguish between high and low depressive subjects within a normal population, Rathus, Reber, Manza and Kushner (1994) found no effect of depression on either implicit or explicit learning in a form of AGL task.

However other clinical studies report findings of impaired implicit learning in depression. Naismith, Hickie, Ward, Scott, and Little (2006) compared implicit sequence learning, as measured by an SRT task, in a group of subjects with moderate to severe unipolar depression and a control group matched for age, gender and education. The comparison revealed impaired implicit sequence learning in the depressed subjects, with an implicit learning rate only half that of control subjects. Moreover, there were no differences in implicit learning between melancholic and non-melancholic depression groups (Naismith, et al., 2006). Similarly Exner, Lange and Irle (2009) reported findings of impaired implicit sequence learning, as measured by a variant of the SRT task. Impaired implicit learning was however confined to the group of depressed subjects with melancholic features, whereas performance of subjects with non-melancholic depression was not distinguishable from that of healthy controls (Exner, et al., 2009).

Mood induction studies. A different approach to studying the effect of mood on implicit learning, which unlike patient studies makes it possible to compare the effect of negative and positive mood states within the same individuals is the use of mood induction in non-clinical populations. Pretz, Totz and Kaufman (2010) studied the effects of mood, cognitive style and cognitive ability on implicit learning, as measured by both an AGL task and an SRT task. The results showed that a negative mood facilitated performance on the AGL task, and a marginal effect in the same direction was observed on the SRT task. Assuming that a negative mood promotes analytical, systematic and detail-oriented, bottom-up processing, Pretz et al. (2010) took the significant finding as evidence of learning being less than fully implicit on the AGL task. Instead they suggested that AGL to some extent requires the type of systematic, analytical and bottom-up processing normally associated with more explicit learning. Even though not referred to, the explanation is in line with the aforementioned mood-as-information approach (e.g. Schwarz, 1990) where negative mood is argued to promote exactly the type of processing referred to by Pretz et al.

Similarly, Braverman (2005) reported a correlation between induced negative mood and enhanced performance on an HCD task, where participants in the negative mood condition detected a covariation between facial nose size and mathematical ability more often than did participants in the positive mood condition.

A plausible interpretation of the findings of worse performance in Braverman’s and Pretz et al.’s positive mood conditions compared to that of the negative mood conditions is that of reduced motivation to elaborate information in the environment in the positive mood conditions at the risk of changing the mood (Wegener, et al., 1995). This is supported by the findings of an additional experiment by Braverman (2005), which tested the assumption that motivation could be a mechanism through which mood affects performance. By implementing an external motivation, performance in the positive mood condition significantly increased, and there was no longer an effect of mood in the high motivation groups. As suggested by Braverman (2005) it is possible that HCD should not be considered a purely implicit learning task, but may require close data observation and elaboration of the details. If this is the case, the facilitated effect of negative mood on performance is in line with the aforementioned mood-as-information approach (Schwarz, 1990). However, the fact that the difference between the negative and positive mood condition groups remained stable even under increased cognitive load, as measured by a distractor task, suggests that learning was unlikely to be fully explicit.

In light of the so far mentioned studies of the effect of depression and mood on implicit learning, it is evident that the experimental procedures applied differ considerably and that the findings are largely contradictory. Some findings report impaired implicit learning in depression, while others report no effect of depression on implicit learning, and still others report a facilitative effect of negative mood on implicit learning.

Methodological concerns in studies of mood and implicit learning. I now turn to some methodological concerns which may contribute to explaining why different studies across clinical and non-clinical populations have shown contrasting results, and which should be taken into account when studying the effect of mood on implicit learning.

Firstly, although mood induction procedures seem to give rise to a level of negative affect that corresponds to levels of mild clinical depression (Martin, 1990), it is still plausible to suspect that there are qualitative and quantitative differences involved in clinical depression and experimentally induced mood states. If so, such differences might contribute to the contradictory findings across clinical and non-clinical studies. However, although induced mood states must be considered as rather low-intensity mood states compared to the intense states of emotion involved in clinical depression, there is substantial evidence that these low-level form of feeling states are potent in influencing both cognition and behaviour (Isen, Means, Patrick, & Nowicki, 1982). Nevertheless, as most of the perspectives of the effect of mood on information processing entail different predictions for positive and negative mood, the predictions cannot merely be tested by means of patient studies investigating the effect of depression on implicit learning. As such, the use of mood induction enables an investigation of the effects of both positive and negative mood states on implicit learning as opposed to the studies on the effect of clinical depression on implicit learning. As demonstrated by previous studies on self-reported mood (Watson, Clark, & Tellegen, 1988; Watson & Tellegen, 1985), negative and positive mood states are not opposite ends of a continuum, but rather orthogonally related.

However, the use of mood induction in implicit learning represents a methodological challenge. Because traditional implicit learning experiments are often monotonous and strenuous they might thus pose activation of different feeling states such as boredom and irritation, which might interfere with the intended mood induction. With both the mood induction manipulation and the mood induction check completed before the actual experimental task, as in the study by Pretz et al. (2010), one might therefore run the risk of the intended induction not necessarily lasting throughout the experiment.

Another factor that might contribute to the contradictory findings across studies is a lack of sufficient control over the extent to which learning was completely implicit. With regards to the possible predictions of the effect of mood on implicit learning, this is of great importance as the mentioned models entail contrasting predictions of the effect of mood contingent on the task requirements. The studies reviewed so far can roughly be divided into studies that measure the effect of mood on a single implicit learning task (e.g. AGL or SRT task) and studies comparing implicit and explicit learning using different tasks. However, the degree to which different experimental procedures, e.g. AGL and SRT tasks, are considered to represent measures of a unitary implicit learning construct is debatable (Gebauer & Mackintosh, 2007). The use of two different tasks to measure implicit and explicit learning is on the other hand potentially problematic as the use of two different tasks involves other aspects beyond merely involving implicit or explicit processes. As a case in point, in Abrams and Reber's study (1988), implicit learning was measured by a traditional AGL task and explicit learning by a simple arithmetic task. In the study by Pedersen et al. (2009), a traditional SRT was used to measure implicit learning and a considerably simpler sequence generation task was used to measure explicit learning. The use of an SRT task where the extent to which learning is implicit or explicit can be manipulated by varying the interval between making a response to one target stimulus and the appearance of the next target stimulus – referred to as the "response-stimulus interval" would enable a comparison between more implicit and explicit learning using the same task. In previous studies (Destrebecqz & Cleeremans, 2001, 2003) longer RSI's have been found to increase explicit representations of the acquired knowledge as well as metacognitive awareness of sequence knowledge, indicating explicit knowledge. In contrast, shorter RSI's are associated with implicit learning.

The aforementioned study by Pretz et al. (2010), where the effect of mood on the SRT task was only marginally significant, included no measure of participants' ability to apply their sequence knowledge on e.g. a recognition or generation task. Therefore, even though Pretz et al.'s study used RSI-0, which is often assumed to promote implicit learning processes, it is difficult to draw any conclusions as to whether the reported effect should be considered to be on more implicit or explicit learning. The use of generation tasks in addition to a training phase, measuring the extent to which participants are able to project their knowledge of the training phase, could have given more insight to the nature of the learning.

Present Study

The present study seeks to further explore and clarify the effect of mood on learning in an SRT task that was specifically designed to meet some of the methodological concerns raised above. Mood induction was used to enable a comparison between positive and negative mood states, and a probabilistic sequence was used to minimize the likelihood that the sequence would be learned explicitly. The study applied two different RSI conditions (RSI-0 and RSI-500), which have traditionally been associated with more implicit and explicit learning, respectively. More specifically, at RSI-0, where the next target stimulus appears instantly after a response, there is no time to consciously anticipate the next target position, which has been hypothesized to promote implicit learning. Whereas with a delay of 500 ms as in the RSI-500 condition, there is time to consciously anticipate the next target position, allowing for the development of more conscious and explicit representations of the sequence (Destrebecqz & Cleeremans, 2001, 2003).

The extent to which participants were able to apply and flexibly control their sequence knowledge was tested by the use of two forms of generation tasks, namely a generation direct task and a generation rotation task (Norman, Price, Duff, & Mentzoni, 2007). The latter is a variant of the standard generation exclusion task. A comparison of performance on these two tasks follows from the widely applied process dissociation procedure, initially developed to dissociate contributions of explicit and implicit memory contributions to performance of a task (Jacoby, 1991). This has been adapted to sequence learning to compare performance on two tasks that differ only by the instructions (e.g. Destrebecqz & Cleeremans, 2001). On the generation direct task participants are instructed to predict the next target positions based on a series of two-trial sequence fragments. On the generation rotation task the instruction is to rotate their actual prediction according to a post-trial-cue. The latter task requires a high degree of global accessibility, referring to the extent to which knowledge can be applied flexibly according to varying task instruction. Within Baars' Global Workspace theory (Baars, 1988), global accessibility is considered to characterize conscious processing.

Furthermore, the study applied a novel and more stringent mood induction procedure where mood induction was integrated as part of the experimental task to ensure a continuous effect throughout the experimental task. This was achieved by replacing the target stimulus with the picture of facial expressions of either happiness or sadness, which constituted the positive and negative mood condition respectively. Mood induction with photographs of happy and sad facial expressions has been shown to be an ecologically valid and socially relevant way of effectively manipulating mood, for instance by Schneider et al. (1994). The effect of the mood induction was assessed by the Positive and Negative Affect Scale (Watson & Clark, 1994) at the end of the experiment as opposed to an assessment before the actual experimental task as in Pretz et al.'s (2010) study. An additional effect of the current applied mood induction procedure is that of increasing perceived task complexity, because the stimulus displays would vary along dimensions such as gender, age and hair colour, in addition to target position.

Finally, the study explored whether decision strategy had an effect on performance on the two generation tasks, by instructing half the participants to use explicit strategies and half the participants to use implicit strategies when solving the generation tasks.

It was predicted that participants in both RSI conditions would show sequence learning as measured by various RT and error measures. Based on previous findings (Norman, et al., 2007) it was predicted that successful generation direct performance would be observed in both RSI conditions, but that RSI-500 participants would show better performance than RSI-0 participants on the generation rotation task.

However, it was further predicted that the effect of mood on learning would be different in the two RSI conditions. If performance was unaffected by mood at RSI-0 this would be compatible with the predictions made by Abrams and Reber (1988). Based on a global versus local perspective, mood-as-information and hedonic contingency approaches it was predicted that a negative mood would be associated with more learning than a positive mood at RSI-500, and that a positive mood would be associated with more learning than a negative mood at RSI-0 given no other motivational factors (cf. the hedonic contingency view). This is based on the assumption that performance at RSI-0 is promoted by holistic and less effortful processing, and performance at RSI-500 is promoted by analytical, systematic and detail-oriented processing.

If generation performance were higher among participants instructed to use explicit strategies, this would indicate explicit learning. In contrast, higher performance for implicit instructions would indicate that participants did not have full conscious awareness of their knowledge and that learning therefore was more implicit.

Assuming that a negative mood is associated with more analytical/explicit decision strategies and a positive mood with more intuitive/implicit strategies it was finally predicted that strategy would moderate the effect of mood on generation performance, where the combinations positive/RSI-0/implicit instructions and negative/RSI-500/explicit instructions would be advantageous.

Method

Participants and Screening

Eighty students (48 women, 32 men, M_{age} = 22.8 years; age range: 19-33 years) were recruited by phone, among a larger sample of students that had signed up for participation in the study at lectures at the University of Bergen and the University College of Bergen. Exclusion criteria included the presence of any diagnosis of psychological disorder or current treatment for psychological disorder, as reported by potential participants when contacted by phone. Participants received the equivalent of €12.50 for their participation. The duration of the experiment was either 45 minutes (RSI-0 condition) or 1 hour (RSI-500 condition).

Materials

Apparatus. The SRT task was programmed in E-prime 2 on a Pentium 4 PC and displayed by an 18" Dell Monitor with 85 Hz vertical refresh. Viewing distance was approximately 55 cm. All instructions were presented on a screen in Norwegian. Rating materials were presented in paper format. Participants were tested in groups of 3-5 in individual cubicles in a psychology testing room.

Stimuli. The target stimulus was always a colour picture of a human face on a grey background. The pictures were taken from FACES 3.3.1. FACES is a database of images of naturalistic faces of 171 younger, middle-aged and older women and men, each person displaying facial expressions of neutrality, sadness, disgust, fear, anger and happiness (Ebner, Riediger, & Lindenberger, 2010). For the purpose of this experiment 32 individual faces were chosen (balanced for age, gender, and hair colour). On each of two sets of pictures used in the current experiment, each person expressed emotions of either happiness or sadness.

Procedure

Mood manipulation. The mood manipulation consisted of pictures of facial expressions of happiness or sadness as target stimuli, in both training phase and generation tasks. On each trial, 32 individual faces, mentioned above, were randomly selected. Half the participants were exposed to happy facial expressions, i.e., the positive mood condition and half were exposed to sad facial expressions, i.e., the negative mood condition (see Appendix, examples A and B).

SRT task. The experiment consisted of a training phase and two different types of a sequence generation tasks - one *generation direct task* and one *generation rotation task* (Norman, et al., 2007).

Training phase. Participants were told that the experiment was about decision-making in complex stimulus environments. On each of the 1470 training trials, a photographic image of a human face appeared in one of four black frames positioned in a square layout (Norman, et al., 2007). Each square was 5.7 cm wide and 5.9 cm high, placed within a larger frame display of 21x21 cm (see Appendix for an illustration of the stimulus displays). The four positions referred to 1 (upper left of the square), 2 (upper right of the square), 3 (lower left of the square) and 4 (lower right of the square). Position was determined by one of two second-order conditional (SOC) sequences (Reed & Johnson, 1994), where target location on each trial was determined by the location on the two preceding trials. The sequences were: 342312142241 (SOC1) and 341243142132 (SOC2). These sequences are balanced for frequency of position, frequency of transition between pairs of positions, position reversal frequency, and the average number of positions encountered until all possible positions had occurred (Norman, et al., 2007). 40 participants (20 negative, 20 positive) were randomly assigned SOC1 as their main sequence, and 40 (20 negative, 20 positive) were randomly assigned SOC2.

The training phase consisted of 14 training blocks (blocks 1-12 and blocks 14-15) and one transfer block (block 13), each block consisting of 98 trials. In each training block, the likelihood that the target would appear in the position predicted by SOC1 on any given trial was 0.875 for SOC1 participants and 0.125 for SOC2 participants, and the likelihood that it would appear in the position predicted by SOC2 was 0.125 for SOC1 participants and 0.875 for SOC2 participants. The probability was switched in the transfer block, with a reversed likelihood for the target appearing in the position predicted by SOC1 (0.125) and SOC2 (0.875) for SOC1 participants and vica versa for SOC2 participants.

Participants were instructed to indicate the position of each appearing target stimulus as fast and as accurately as possible by pressing one of four keys on a numeric keypad, corresponding to the current location (keys 7, 9, 3, 1). Moreover, fingers were to be placed on the numeric key pad as following: left index finger – 1; left middle finger – 7; right middle finger – 9; right index finger – 3. The target stimulus was removed from screen as soon as a response had been made. Regardless of whether the response was correct or not, a new stimulus appeared either instantly after responding (for participants in the RSI-0 condition) or after a delay of 500 ms (for participants in the RSI-500 condition). After each block, participants were presented with an on-screen feedback display, stating their mean RT and number of incorrect responses for the completed block.

Generation phase. After the training phase all participants performed two types of cued generation tasks, with the same target stimuli as in the training phase. On each trial of the *generation direct task*, participants were presented with a brief sequence of two target moves. In both RSI conditions each stimulus was presented for 1000 ms, with an interval of either 0 ms (RSI-0 condition) or 500 ms (RSI-500 condition) between the two stimuli. After each brief sequence, four unfilled black squares replaced the shapes, and the appearance of a question mark in the centre of the screen indicated that the participants had to predict the next target position by pressing corresponding keys (7, 9, 3, 1) as in Wilkinson & Shanks (2004) and Norman et al. (2007). The chosen position was then highlighted. Participants initiated the next trial, as s/he was ready.

On a second version of the generation task, named the *generation rotation* task (Norman, et al., 2007), participants were again presented with a series of two-trial sequence fragments using the same procedure as for the generation direct task. However, after each sequence had been completed, one of the numbers “+1”, “-1, or “-2” was presented. The instructions were that “+1” indicated a clockwise rotation of one position, that “-1” indicated an anticlockwise rotation of one position and that “-2” indicated an anticlockwise rotation of two positions. The task was to predict the next position, but before responding, the participants were informed to take into account the instruction to rotate their response as indicated by the actual number shown. Thus a successful response required an integration of their judgement as to what the next position would be with the varying post-trial cue. This type of generation task is assumed to require a greater degree of flexible control over the predicted next sequence position as compared to the generation direct task or the standard *exclusion* task commonly used in SRT studies (Norman, et al., 2007) All participants completed the generation direct task before the generation rotation task. Each generation task consisted of 36 trials.

Decision strategy manipulation. The purpose of a manipulation of decision strategy was to get different subgroups of participants to perform the generation tasks using either an explicit strategy or an implicit decision strategy (Dienes & Scott, 2005).Thus, on both of the generation tasks each subgroup received the same instructions. Participants in the *implicit instruction* condition were told to base their response on what felt right according to the sequences they had been shown in the first part of the experiment. In the *explicit instruction* condition, participants were told to base their response on what they remembered and what they thought the rule was. Before pressing start to continue the next trial, a reminder of the instructions was given.

PANAS-X. In order to measure the effect of the mood manipulation on self-reported mood, participants were given a Norwegian version of Positive and Negative Affect Scale (PANAS-X) in paper format after completing the two generation tasks (Watson & Clark, 1994). The scale consists of a number of words and phrases describing different emotions. The original PANAS-X was translated into Norwegian by a bilingual and back translated into English by a native speaking individual[1]. For the purpose of this experiment the general dimension scales (negative and positive affect), basic negative emotion scales and basic positive emotion scales from PANAS-X were included, whereas the other affective states scales were omitted. The subscales of interest were (1) Sadness (*sad, blue, downhearted, alone and lonely*) and (2) Joviality (*happy, joyful, delighted, cheerful, excited, enthusiastic, lively and energetic*), and (3) Attentiveness (*alert, attentive, concentrating and determined*). Sadness is a subscale of the basic negative emotion scale, whereas joviality and attentiveness are subscales of the basic positive emotion scale (Watson & Clark, 1994). For each adjective, participants were instructed to indicate to what extent they felt this way here and now using a 5-point scale (1 *very slightly or not at all*; 2 *a little*; 3 *moderately*; 4 *quite a bit*; 5 *extremely*).

Results

Analyses were based on data from all 80 participants. Analyses of the generation tasks were based on data from 79 participants and excluded data from one participant not following the instructions on the generation rotation task.

[1] Two items that were back translated differently were discussed by the translators. “Upset” was kept and “strong” was changed from “iherdig” to “strong”.

Mood Induction Check

The internal consistencies of the three PANAS subscales of interest were assessed by calculating Cronbach's α, which reflects the average correlation between the different items within each scale (Cronbach, 1951). This was high both for Joviality ($\alpha = .91$), Sadness ($\alpha = .81$), and Attentiveness ($\alpha = .76$). As predicted, participants in the positive mood condition showed significantly higher mean scores on Joviality ($M = 20.68$, $SE = 0.95$) than participants in the negative mood condition ($M = 17.63$, $SE = 0.99$), $t(78) = 2.23$, p(two-tailed) = .03. Participants in the negative mood condition had significantly higher mean scores on Sadness ($M = 9.45$, $SE = 0.61$) than participants in the positive mood condition ($M = 7.28$, $SE = 0.41$), $t(78) = 2.96$, p(two-tailed) = .004. There was no significant difference between the two groups in terms of Attentiveness, $p = .67$, reflecting that the significant group difference on Sadness and Joviality was not due to general arousal levels, but rather a changed valence of emotion. There were no other significant differences between the two groups except for the subscale Fear ($\alpha = .59$), where participants in the negative mood condition ($M = 9.70$, $SE = 0.50$) had significantly higher mean score than participants in the positive mood condition ($M = 8.38$, $SE = 0.35$), $t(78) = 2.19$, p(two-tailed) = .03. As the subscale Fear is part of the basic negative affect scale, the finding is in the predicted direction.

RT Data from Training Phase

Mean overall RT, mean RT on probable trials and mean RT on improbable trials were calculated separately for each block of trial for each participant. All RTs were 2 SD trimmed. Error trials and trials with RTs below 100 ms were also excluded.

In a probabilistic sequence learning experiment (Kaufman, et al., 2010; Norman, et al., 2007), learning of the training sequence would be indicated by a greater gradual reduction of RT across training blocks for probable than improbable trials. As there were only 12 improbable trials in each experiment block, mean RT for each participant on the two types of trials were calculated across pairs of successive blocks and excluding block 13[2], resulting in 7 blocks in total. A mixed ANOVA with mean RT as the dependent variable, probability (probable vs. improbable) and block (1-7) as within-subject variables, and sequence type (SOC 1 vs. SOC 2) and RSI condition (RSI-0 vs. RSI-500) as between-subject variables, revealed no main effect or interactions involving sequence type, i.e., whether SOC 1 or SOC2 had acted as the main training sequence. The further analyses were thus conducted without SOC.

There was a significant main effect of RSI, $F(1, 78) = 75.77$, $p < .001$, reflecting faster RT at RSI-500 ($M = 335.46$, $SE = 6.28$) than at RSI-0 ($M = 425.67$, $SE = 8.24$) As predicted, there was also a main effect of probability, $F(1,78) = 239.71$, $p < .001$, reflecting faster responses on probable ($M = 368.65$, $SE = 5.22$) than on improbable trials ($M = 392.47$, $SE = 5.26$). A significant main effect of block, $F(6, 468) = 20.74$, $p < .001$, reflected an overall decrease in RT over the training phase. Most importantly, there was an interaction between probability and block, $F(6,468) = 21.56$, $p < .001$. A post-hoc analysis (Tukey's HSD test) showed that the difference in RT between probable and improbable trials was significant in all blocks except for block 1, $p < .05$. This interaction between probability and block, reflecting a difference in RT between probable and improbable trials for different blocks of the experiment, was not influenced by RSI (See figure 1).

(Figure 1 about here)

[2] An analysis of the RT increase from block 12 to block 13 confirmed that learning took place at both RSI conditions, but will not be reported here.

Another indicator of sequence learning is a relative increase in key-press errors on improbable trials compared to probable trials across blocks. An identical ANOVA with the proportion of errors on probable versus improbable trials as the dependent variable showed no main effects or interactions involving SOC, which was therefore excluded from the analysis. There was a significant main effect of probability, $F(1, 78) = 85.81$, $p < .001$, reflecting more key-press errors on improbable ($M = 0.10$, $SE = 0.01$) than probable ($M = 0.06$, $SE = 0.00$) trials. There was also a main effect of block, $F(6,468) = 7.09$, $p < .001$, indicating that the tendency to make errors increased across blocks. Importantly, there was a significant interaction between probability and block, $F(6, 468) = 3.93$, $p < .001$, indicating a greater increase in key press errors across blocks on improbable trials than probable trials. A post-hoc analysis (Tukey's HSD test) showed that there was a significant effect of probability in all blocks except for block 1, $p < .05$ (see figure 2).

(Figure 2 about here)

A second error analysis (conducted on the same blocks) looked only at errors made on *improbable* trials. Learning is indicated if errors that involve selecting the position predicted by the probable sequence are made more often than other errors. The selection of a position predicted by the probable sequence on an improbable trial is referred to as a *wrong sequence error (WSE)*. A mixed ANOVA with the absolute number of errors on improbable trials as the dependent variable, error type (WSE vs. other errors) and block (1-7) as within-subjects variables, and sequence type (SOC 1 vs. SOC 2) and RSI condition (RSI-0 vs. RSI-500) as between-subjects variables, showed that none of the critical main effects or interactions were influenced by SOC, which was therefore removed from the analyses. There was a significant main effect of error type, $F(1, 78) = 33.85$, $p < .001$, reflecting a tendency to make more WSE

(M = 0.82, SE = 0.07) than other errors (M = 0.41, SE = 0.04) on improbable trials. There was a significant main effect of block, $F(6, 468) = 5.87$, $p < .001$, indicating that the tendency to make both types of errors increased over blocks. There was also a significant interaction between error type and block, $F(6, 468) = 4.46$, $p < .001$. A post-hoc analysis (Tukey's HSD test) showed that there was a tendency to make WSE more often than other errors on blocks 3, 5, 6 and 7, $p < .05$ (see figure 3).

(Figure 3 about here)

There was also a significant three-way interaction between error type, block and RSI, F (6, 468) = 2.45, $p = .02$. A post-hoc analysis (Tukey's HSD test) showed that the tendency to make more WSEs than other errors was more consistent across blocks at RSI-0, where there was a significant difference between the two error types in blocks 4, 5, 6 and 7. At RSI-500 the two error types differed only in block 6, $p < .05$.

Mood and RT performance. To analyse the effect of mood on learning, an ANOVA was conducted with the difference in mean RT for probable versus improbable trials across all blocks as the dependent variable. For each participant the RT difference score was calculated from trimmed mean RTs for paired blocks except for combined block 1. Combined block 1 was excluded, as the difference in RT between probable and improbable trials was significant in all blocks except for block 1, as mentioned above. Mood and RSI were independent variables. The analysis revealed a significant main effect of RSI, $F(1, 76) = 12.66$, $p < .001$, reflecting a significantly higher mean RT difference score at RSI-0 (M = 32.72, SE = 2.63), than at RSI-500 (M = 21.38, SE = 1.95). There was no main effect of mood. Importantly, there was a significant interaction between mood and RSI, $F(1, 76) = 6.07$, $p = .02$. The prediction that a negative mood would be associated with more learning than a positive mood at RSI-500, and that a positive mood would be associated with more learning than a negative mood RSI-0 was tested by a set of planned comparisons. At RSI-500 there was a near-significant trend for better performance among participants in the negative mood condition (*M* = 25.73, *SE* = 2.52) than in the positive mood condition (*M* = 17.02, *SE* = 2.69), $F(1,76) = 3.74$, $p = .057$. There was no such difference at RSI-0 between the negative mood condition (*M* = 29.22, *SE* = 3.27) and the positive mood condition (*M* = 36.21, *SE* = 4.04), $F(1.76) = 2.40$, $p = .13$. Because of the significant main effect of RSI any comparisons across RSI should be interpreted with caution. However, it may be worth noting that a post-hoc analysis (Tukey's HSD test) showed that for positive mood participants, RT differed across the RSI conditions ($p < .001$), but this was not the case for negative mood participants ($p = 0.87$), (see figure 4).

(Figure 4 about here)

Generation Performance

Performance on the two types of generation tasks at the two RSI's was compared in a mixed ANOVA with the number of correct generation responses as the dependent variable, and sequence type, RSI, instruction (implicit vs. explicit) and generation task (direct vs. rotation) as independent variables. There were no main effects or interactions involving sequence type or instruction, which were therefore removed from the analysis. A significant main effect of generation task, $F(1, 77) = 9.21$, $p = .003$, reflected better performance on the direct (*M* = 15.42, *SE* = 0.37) than on the rotation task (*M* = 13.86, *SE* = 0.53). There was no main effect of RSI, and no interaction between generation task and RSI. Performance on both generation tasks was compared to a chance level of 12, which is the statistical probability on the 36 trials of the target appearing in each of the three possible target positions, given that the target never appears in the same position twice in a row. The comparison of performance to chance (12) in both RSI conditions revealed performance significantly above chance on the direct task at RSI-0 (M = 14.98, SE = 0.57), $t(40) = 5.25$, $p < .001$, and RSI-500 (M = 15.87, SE = 0.47), $t(39) = 8.15$, $p < .001$. Performance on the rotation task was better than chance only at RSI-500 (M = 14.51, SE = 0.69), $t(39) = 3.65$, $p < .001$.

Mood and generation performance. An ANOVA with RSI, mood and instruction (direct vs. rotation) as independent variables, and generation score as the dependent variable, revealed no main effect of mood condition. However, there was a significant interaction between generation task and mood $F(1, 72) = 6.91$, $p = .01$. A post-hoc analysis (Tukey's HSD test) showed that participants in the negative mood condition performed significantly worse on the generation rotation task than on the generation direct task, $p < .001$, whereas performance did not differ for the two tasks in the positive mood condition.

There was no significant interaction between generation task, mood and RSI. However a set of t-tests comparing generation performance to chance (12) for each combination of mood and RSI showed that performance was above chance in all conditions, $p < .05$, except in the RSI-0/negative mood condition, where participants performed at chance on the rotation task (M = 12.00, SE = 1.32), $t(19) = 0.00$, p (two-tailed) > .95 (see figure 5).

(Figure 5 about here)

Discussion

The purpose of the current study was to further explore and clarify the effect of mood on learning in the SRT task, where participants were trained under two different conditions differing by the length of the response stimulus interval (RSI-0 and RSI-500), as well as two different mood conditions (positive and negative).

The study was designed to avoid some of the methodological shortcomings in the existing literature (e.g. Abrams & Reber, 1988; Pedersen, et al., 2009; Pretz, et al., 2010; Reber, et al., 1991) by applying two different RSI conditions, as well as employing objective measures of the ability to apply and flexibly control sequence knowledge by the use of two different types of generation tasks. Finally, mood was induced throughout the experimental task by using target stimuli that were pictures of facial expressions of happiness and sadness, and assessed at the end of the experiment.

The Usefulness of the New Mood Induction Procedure

The results of the current study show that with a new mood induction procedure, whose aim was to ensure continuous mood induction throughout the experimental task, mood induction was effective. More specifically, the replacement of a traditional target stimulus with a picture of a human face either expressing sadness or happiness, was effective as indicated by significantly higher scores on the subscale Joviality in the positive mood condition and significantly higher scores on the subscale Sadness in the negative mood condition. Importantly, there were no significant group differences on the subscale Attentiveness, which indicates that the significant group difference on the subscales Sadness and Joviality was caused by a changed *valence* of emotion rather than general arousal levels. The current study is thus an example of how to induce mood in an implicit learning task in a way that ensures a continuous mood induction throughout the experiment, with a resulting effect even on positive mood. The latter is particularly important in light of the aforementioned possibility that exposure to implicit learning experiments might activate boredom or irritation.

The Relationship between Mood and Sequence Learning

Sequence learning occurred at both RSI-0 and RSI-500, which is in accordance with findings from previous studies (e.g. Destrebecqz & Cleeremans, 2001; Norman, et al., 2006; Norman, et al., 2007).

The results revealed no significant main effects of mood on learning, but as predicted there was a significant interaction between mood and RSI. To recap, in the RSI-0 condition the next target stimulus appears instantly after making a response, whereas in the RSI-500 condition there is a time delay of 500 ms. Longer RSI's (as the RSI-500 condition in the current study) have been argued to promote more explicit learning by giving participants more opportunities to combine high-quality memory traces and develop stronger representations of the sequence compared to no-RSI conditions (Destrebecqz & Cleeremans, 2003).

Interestingly, at RSI-500 there was a near-significant trend for more learning for negative mood than positive mood participants. In other words, in the RSI-500 condition, which is regarded as a zone of more explicit learning, negative mood was more beneficial. To the extent that the current mood induction bears any resemblance to negative mood states involved in depression, this is in contrast to the predictions by Reber and Abrams (1988), where the more recently evolved explicit system is hypothesized to suffer under conditions of depression. The finding does however give support to the local versus global perspective, and mood-as-information and hedonic contingency approaches, as negative mood is beneficial under conditions (RSI-500) promoted by a more local, analytical, detail-oriented and systematic processing style. As a case in point, a recent study by von Helversen et al. (2011) reported findings of performance benefits of depression on a sequential decision making task. Because this task is likely to involve more explicit processing, these findings are therefore in line with the performance benefit of negative mood in the current RSI-500 condition. That is, contrary to various reported findings of detrimental effects of depression (e.g. Eizenman, et al., 2003; Gotlib & Joormann, 2010; Matthews & MacLeod, 2005), some cognitive tasks seem to benefit from depression in von Helversen study, and by induced negative mood in the present study. One explanation may be that depression and negative mood lead to a more analytical, detail-oriented and systematic processing style.

At RSI-0 there was no difference in the amount of learning between participants in the negative mood and in the positive mood conditions. This is in contrast to the predictions inferred from a global versus local perspective, mood-as-information and hedonic contingency approaches. When the task at hand does not require effortful, local, analytical and detail-oriented processing, which is the case at RSI-0, the models predict a positive mood to be beneficial. A negative mood would in contrast be predicted to be less advantageous under these circumstances as it is assumed to promote a more local, effortful, analytical and detail-oriented approach. Accordingly, the finding of no difference between the two mood conditions at RSI-0 is unexpected. The finding is however in line with the predictions inferred from Reber (1989), where tasks involving implicit learning should show less individual variation than tasks involving explicit learning.

The finding of no difference between positive and negative mood conditions at RSI-0 is also contradictory to the reported findings of a marginally significant effect of mood in SRT task as reported by Pretz et al. (2010), where participants in the negative mood condition showed the highest implicit learning scores. However, there are a number of methodological differences between Pretz et al.'s study and the current study, which may explain this apparent divergence. Firstly, the picture stimuli used in the current study were multidimensional in the sense that individual faces varied in terms of gender, age and hair colour. This introduces a perception of increased task complexity, whereby it becomes more difficult for participants to form partial or complete explicit knowledge of the sequence than when the target stimulus is always the letter "x" as in the study by Pretz et al. (2010). Secondly, the current study applied two RSI conditions (RSI-0 and RSI-500) as well as more direct measures of participants' awareness or global accessibility of the acquired knowledge. Pretz et al.'s use of simple stimulus displays, without any direct measure of participants' ability to apply their knowledge or a high-RSI condition against which performance can be compared, raise the question of whether their RSI-0 condition was indeed associated with *implicit* learning.

However, one aspect of the data nevertheless gives some indication that a positive mood may to some extent have facilitated learning at RSI-0. A post-hoc comparison of the aforementioned interaction between RSI and mood showed that for positive mood participants the RT difference score was larger at RSI-0 than at RSI-500, indicating more learning at RSI-0. Participants in the negative mood condition showed no such difference. This indicates that any advantage of RSI-0 (as observed by a significant main effect of RSI on the RT difference score) was limited to positive mood participants. Even though comparisons across RSI conditions should be interpreted with some caution, this aspect of the data indicates that a positive mood may have been more beneficial at RSI-0, where performance is assumed to be promoted by a global processing and an effortful and analytical processing style is not required, than at RSI-500, where performance is assumed to be contingent on a local, effortful, analytical, detail-oriented and systematic processing. This finding is therefore compatible with the aforementioned global versus local perspective, as well as the mood-as-information and hedonic contingency approaches.

Generation Performance at Different Levels of RSI

Two different forms of generation tasks were included as measures of the extent to which participants showed flexible control over their sequence knowledge. The results revealed a significant main effect of generation task, reflecting better performance on the direct than the rotation task at both RSI's, which is in accordance with previous findings (Norman, et al., 2007). A comparison of performance on both generation tasks to chance revealed performance significantly above chance on the direct task at both RSI conditions. However, performance on the rotation task was better than chance only at RSI-500. From a global workspace theory perspective (Baars, 1988), consciously represented information is characterized by a high degree of global accessibility, referring to the degree knowledge can be applied flexibly with varying task instructions. Because successful rotation performance requires a high degree of global accessibility over knowledge, the results could therefore be taken to indicate that learning was more implicit in the current RSI-0 condition and more explicit at RSI-500. This overall result is compatible with the findings reported by Destrebecqz and Cleeremans (2001, 2003).

Nevertheless, it has also been argued that successful rotation ability at RSI-500 does not necessarily indicate fully explicit learning (Norman, et al., 2007). In other studies, including a recently reported AGL experiment (Norman, Price, & Jones, 2011), we have found that flexible control does not necessarily reflect detailed conscious awareness of the learned rule but can also reflect "fringe consciousness", where conscious feelings reflect unconscious knowledge (Norman et al., 2006, 2007). Therefore the results at RSI-500 are compatible both with explicit learning as well as "fringe consciousness". If future studies of the effect of mood in the SRT task also included subjective measures of awareness, as for instance confidence ratings, this would make it possible to distinguish the two knowledge states.

The Influence of Strategy Instruction on Generation Performance

As mentioned earlier, the generation rotation task can be solved by means of either applying detailed conscious knowledge of the sequence or by introspecting on conscious feelings that may be referred to as "fringe consciousness" (Norman, et al., 2007). From this perspective, the use of an explicit strategy (i.e., trying to remember the sequence) would be more beneficial at RSI-500, where the representations of the sequence are of higher quality. In contrast, an implicit strategy (i.e., responding on the basis of what felt right) would be more advantageous at RSI-0 where the memory representations of the sequence are weaker. The disadvantageous use of an explicit strategy at RSI-0 is captured by Reber's comment "looking for rules will not work if you cannot find them" (1989, p. 223) – whereby participants' attempts to look for rules are detrimental given a lack of high-quality representations of the sequence.

The direct instruction to apply implicit or explicit decision strategies during the generation phase did not influence generation ability on either form of generation task, and did not interact with RSI. Fu, Dienes and Fu (2010) reported that generation performance was different for different subcategories of (implicit or explicit) decision strategies in an SRT task. They measured decision strategy in a conventional manner, i.e., by asking participants to indicate which decision strategy they had used on each individual trial, rather than instructing participants to adopt certain strategies (Fu, et al., 2010). The lack of an effect of decision strategy in the current study may therefore indicate that instruction did not have the intended effect in altering participant's decision strategies. It may well be the case that people do not have voluntary control over the type of decision strategies they apply in this type of situation.

The Influence of Mood on Generation Performance

There was no significant main effect of mood on generation performance, but again there was a significant interaction between generation performance and mood, where participants in the negative mood condition performed significantly worse on the generation rotation task than on the generation direct task. For participants in the positive mood condition, performance did not differ for the two generation tasks.

This might indicate that learning was more implicit for participants in the negative mood conditions (regardless of RSI). Alternatively, it might indicate that the rotation instruction was too demanding in terms of memory and attentional requirements, and thus reduced performance among negative mood participants in line with previous reported effects of depression on memory and attention. However, both of these possibilities are unlikely as revealed by the following comparisons to chance.

Interestingly, a set of comparisons to chance revealed that it was only participants in the negative mood condition at RSI-0 who were unable to perform the rotation task better than chance. In other words, the results indicate that chance performance on the rotation task at RSI-0 may be attributable to a low degree of flexible control of the knowledge among participants in the negative mood condition at RSI-0.

What appears to be a combined influence of both mood and RSI on flexible control may shed light on the difficulty of replicating the findings of Destrebecqz and Cleeremans (2001, 2003), where subjects in the RSI-0 condition were not able to refrain from expressing their sequence knowledge under exclusion instructions. This finding of exclusion task performance being confined to longer RSI conditions has been challenged by later studies (e.g. Norman, et al., 2006; Norman, et al., 2007; Wilkinson & Shanks, 2004). Notably, none of the studies have controlled for differences in mood among participants, and thus it remains unknown whether the reported findings may at least in part have been mediated by individual differences in mood. The findings are also interesting in light of the absence of an effect of mood on learning at RSI-0: Even though the amount of learning seemed not to be influenced by mood, it is evident that positive versus negative mood participants at RSI-0 differed in the degree of flexible control over the acquired knowledge.

A plausible explanation of the rotation performance at chance level in the negative mood condition at RSI-0 pertains to the local versus global perspective, according to which a negative mood promotes focus on the details with enhanced memory of the details at the expense of perceiving the overall picture (Gasper & Clore, 2002; Hills, Werno, & Lewis, 2011 in press), in combination with the RSI-0 manipulation promoting more implicit processes (Destrebecqz & Cleeremans, 2001, 2003). The latter is related to the hypothesis that "consciousness takes time" (Cleeremans & Sarrazin, 2007), where consciousness depends on high-quality representations which take time to acquire. At RSI-500, participants are thus given more opportunities to combine these high quality representations of the sequence as well as develop stronger representations of the sequence. Compared to the generation direct task and the traditional exclusion task, some will argue that the rotation task requires additional conscious insight into the nature of the sequence. The reason why participants in the RSI-0/negative mood condition are not able to perform the rotation task better than chance might therefore be related to a lack of conscious representation of the sequence, as well as an enhanced focus on the details, possibly at the expense of perceiving the more complex and subtle pattern involved. Future studies should therefore further explore a hypothesis of differential attention to the local and global picture involved in positive and negative mood states in the SRT task.

Another related explanation is that mood more specifically influenced the type of decision strategies people used to apply their knowledge during generation tasks, and that different strategies are advantageous in the two RSI conditions. Thus, even though the decision strategy instruction did not appear to have any effect on the application of knowledge, it may be the case that mood may have influenced decision strategy indirectly in the direction predicted by the global versus local processing perspective (e.g. Basso, et al., 1996; Bless & Fiedler, 2006; Bohner & Weinerth, 2001). In a study of artificial grammar learning (AGL), we (Norman, Scott, Jones, Price, & Dienes, in prep) have shown how an “explicit” strategy may be disadvantageous under conditions of more implicit learning. Whereas participants who were aware of the nature of the rule were able to apply their grammar knowledge flexibly on trials where they claimed to be using “explicit” decision strategies, this was not the case for participants who showed more “intuitive” learning - these participants in fact showed a reduction in performance on trials attributed to “explicit” as opposed to “implicit” decision strategies (Norman, et al., in prep). In the context of the current study, if a negative mood caused participants to apply more “analytical”/”explicit” decision strategies, this may explain why participants at RSI-0 in the negative mood condition show impaired performance on the demanding rotation task. This is because a more "explicit" strategy is only advantageous if there are high-quality memory representations of the acquired sequence knowledge. The reason why participants in the positive mood condition at RSI-0 were able to exert flexible control, as evident by performance above chance, may be that their positive mood promoted the use of more “intuitive” /”implicit” strategies.

Bearing in mind that generation performance was not influenced by the instruction to apply implicit versus explicit decision strategies, it is therefore of particular interest that the induction of mood has an ostensibly stronger indirect effect. However this tentative hypothesis that the induction of positive mood may represent an indirect way of manipulating strategy, should be specifically followed up in future studies.

Limitations

Possible limitations of the current study should be noted. Firstly, a neutral mood condition was not included as the current exploration primarily concerned the effect of positive and negative mood on learning in the SRT task. Future studies should, however, include a neutral mood condition to further clarify the effect of mood on learning in the SRT task. Secondly, the manipulation of decision strategy precluded the use of subjective measures of awareness, as participants were explicitly instructed to use different strategies when performing the two generation tasks. Future studies should include subjective measures of awareness, i.e., confidence ratings or self-report judgements of decision strategy, which would make it possible to distinguish between ”fringe consciousness” and explicit learning, as noted previously.

Implications and Conclusions

On a general level, the finding of an interaction between mood and RSI condition is an indication of qualitative differences in learning at the two different RSI conditions. Without the inclusion of the mood variable the effects of RSI on learning and generation ability would have been less evident - however the inclusion of the mood variable revealed a differential effect of mood in the two RSI conditions. The indication of qualitative differences is in line with the findings of differential effect of personality in a study by Norman et al., (2006). Similar to the current study, Norman et al., explored sequence learning at two different RSI (RSI-0 and RSI-250), and found that certain personality factors influenced learning and generation ability differently in the two conditions. Norman et al. argued that the identification of qualitative differences in learning at different RSI conditions, as evident by an effect of individual differences, could explain contradictory findings reported across studies despite similar experimental procedures. Based on the results from the current study one may similarly speculate as to whether uncontrolled individual differences in mood may have contributed to inconsistencies across previously reported findings of the influence of RSI. Only moderate differences in mood were sufficient to influence performance in the SRT task, and the influence was different across the two RSI conditions. By illustrating how mood may be influenced by subtle manipulations, the study also has implications for implicit learning research procedures, and – depending on the research question – whether mood should be included as a variable.

On a more general level, the study has implications for the understanding of cognitive mechanisms involved in depression, by indicating some possible benefits of negative mood on cognitive tasks in line with the reported findings by von Helversen et al (2011). Furthermore, research on implicit learning is argued to have implications for cognitive psychotherapy, with a more recent focus on the underlying cognitive schemata operating at a more implicit level compared to a former focus on conscious thoughts and images (Dowd & Courchaine, 1996). As a case in point, the current exploration of the effect of mood on learning in the SRT task could be of contribution to the understanding of how mood might influence the operation of these cognitive schemata.

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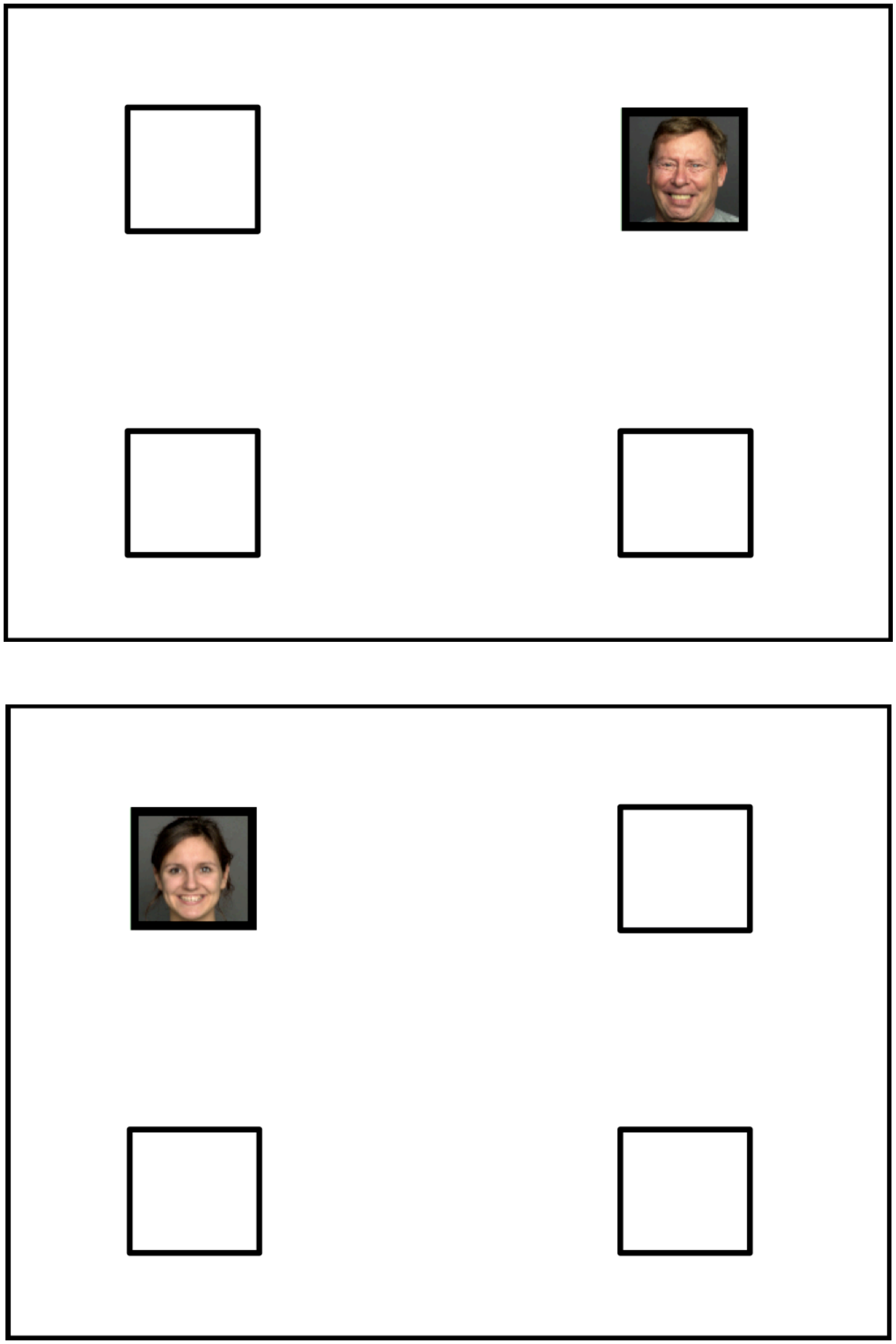
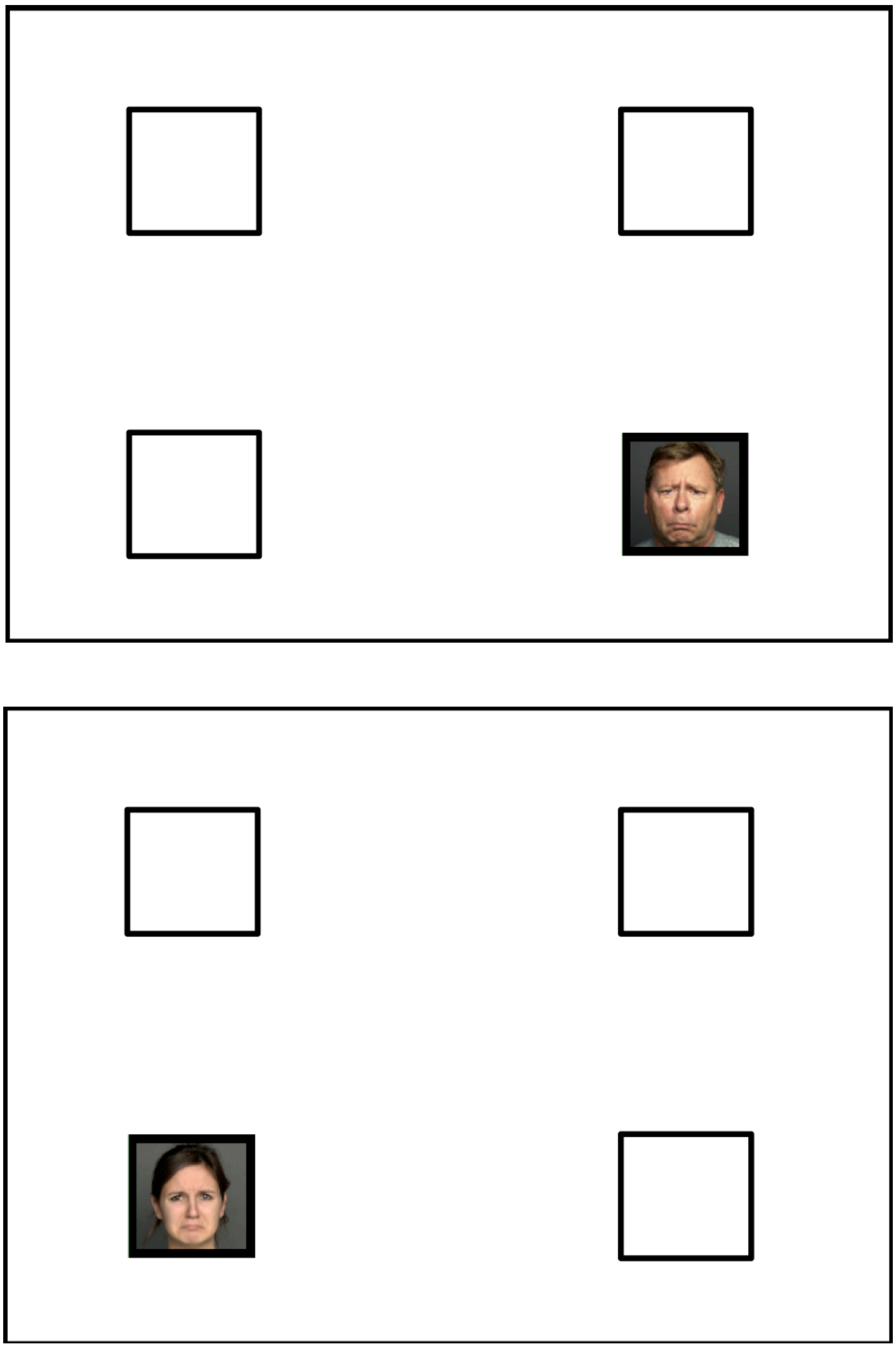
Appendix



(A) An example of two picture displays in the positive mood condition, with the target stimulus being in stimulus position 2 (top) or stimulus position 1 (bottom).



(B) An example of two picture displays in the negative mood condition, with the target stimulus being in stimulus position 3 (top) or in stimulus position 4 (bottom).

Figure Captions

Figure 1. Mean reaction time (RT) (±*SE*) on probable versus improbable trials across successive (combined) training blocks plotted separately for each RSI condition.

Figure 2. Proportion of key press errors (±*SE*) on probable versus improbable trials across successive (combined) training blocks, plotted separately for each RSI condition. There was a greater increase in key press errors across blocks on improbable trials than probable trials.

Figure 3. Number of wrong sequence errors (±*SE*) compared to other errors on improbable trials across successive (combined) training blocks. The tendency to make more wrong sequence errors (WSE) than other errors increased across successive blocks.

Figure 4. Mean RT difference score (±*SE*), plotted separately for each RSI and mood condition. Higher scores indicate more learning. There was no effect of mood on RT at RSI-0, but a near significant trend for more learning among negative than positive mood participants at RSI-500.

Figure 5. Comparisons of number of correct generation responses (±*SE*) completed in line with the main training sequence, compared to a chance level of 12, as indicated by the dotted line. There was above chance performance in all conditions, except for participants in the negative mood condition at RSI-0 on the rotation task.

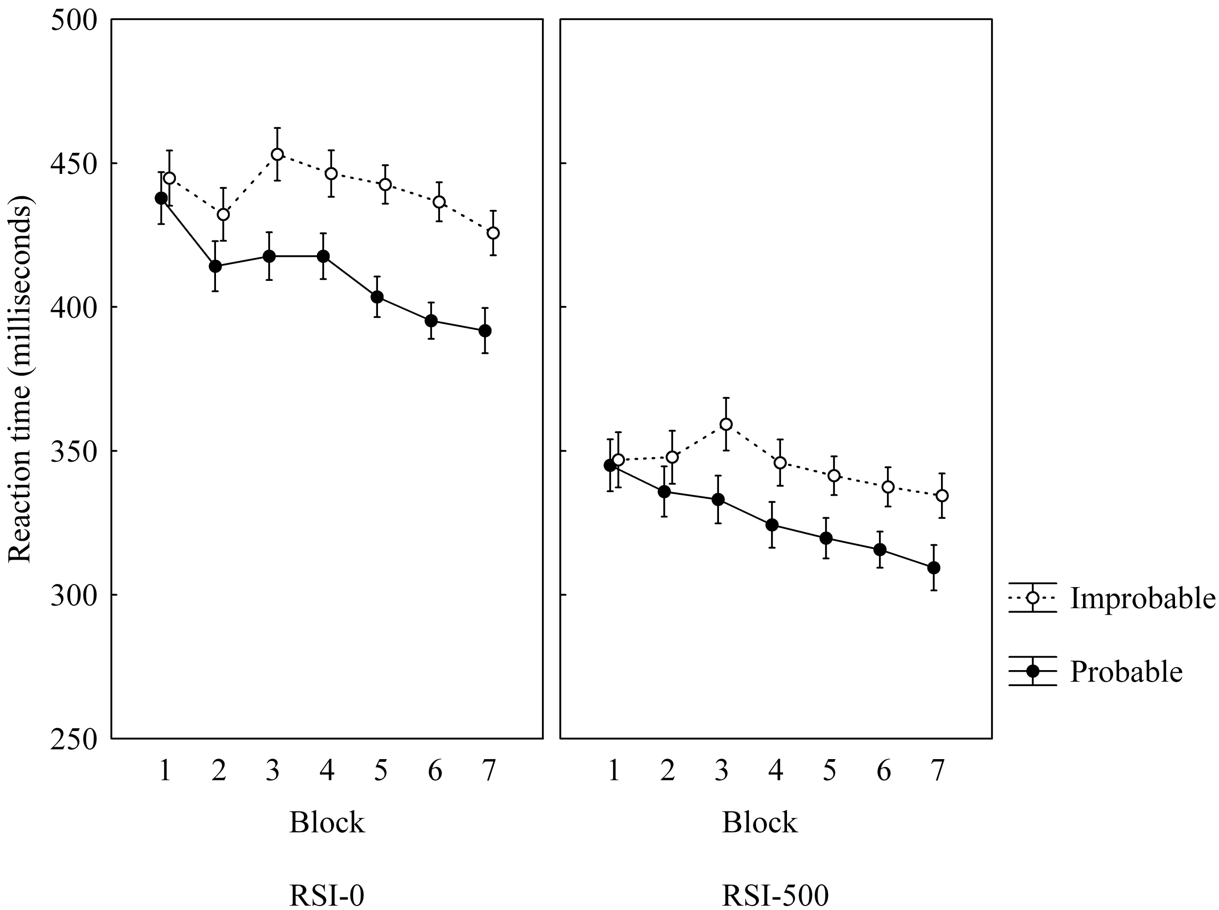

500
450
400
350
300
250
Reaction time (milliseconds)
1 2 3 4 5 6 7
Block
RSI-0
1 2 3 4 5 6 7
Block
RSI-500
Improbable
Probable

Figure 1.

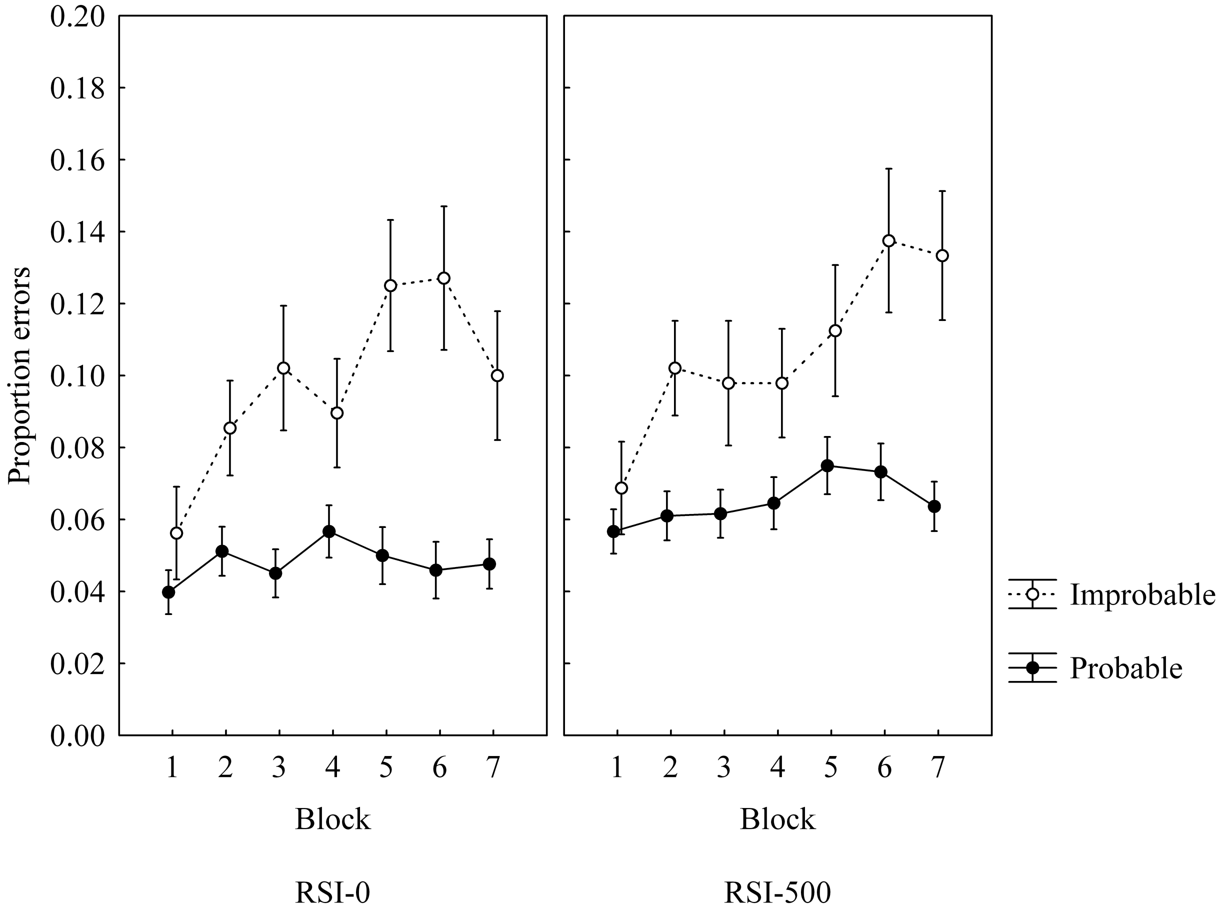

0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Proportion errors
1 2 3 4 5 6 7
Block
RSI-0
RSI-500
Improbable
Probable

Figure 2.

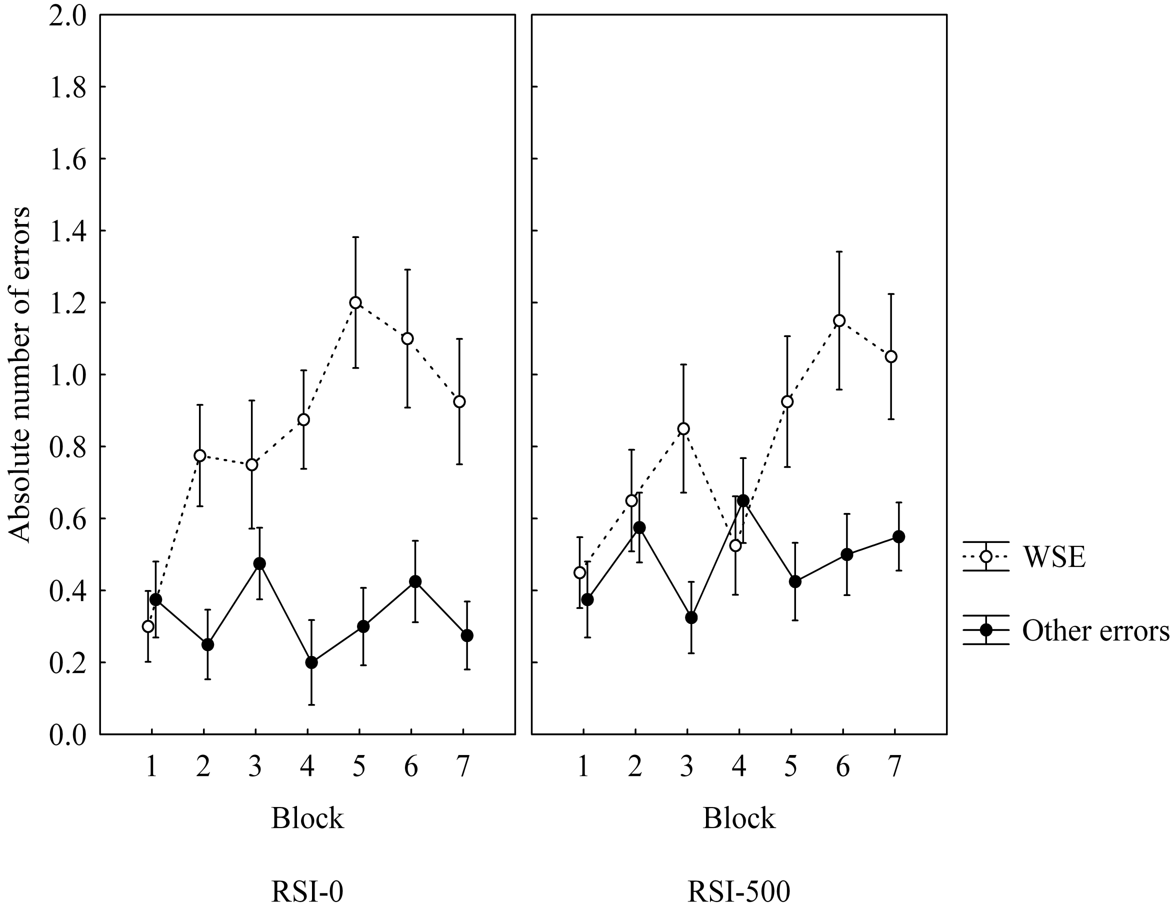

2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Absolute number of errors
1 2 3 4 5 6 7
Block
RSI-0
1 2 3 4 5 6 7
Block
RSI-500
WSE
Other errors

Figure 3.

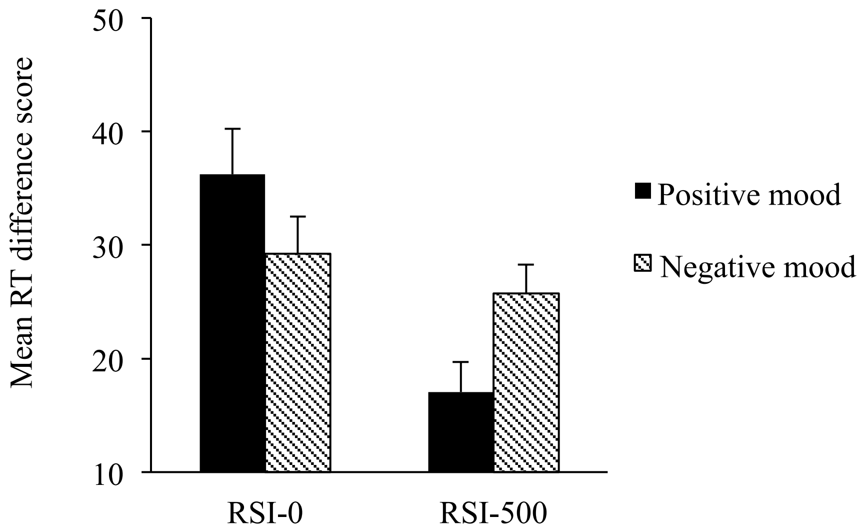
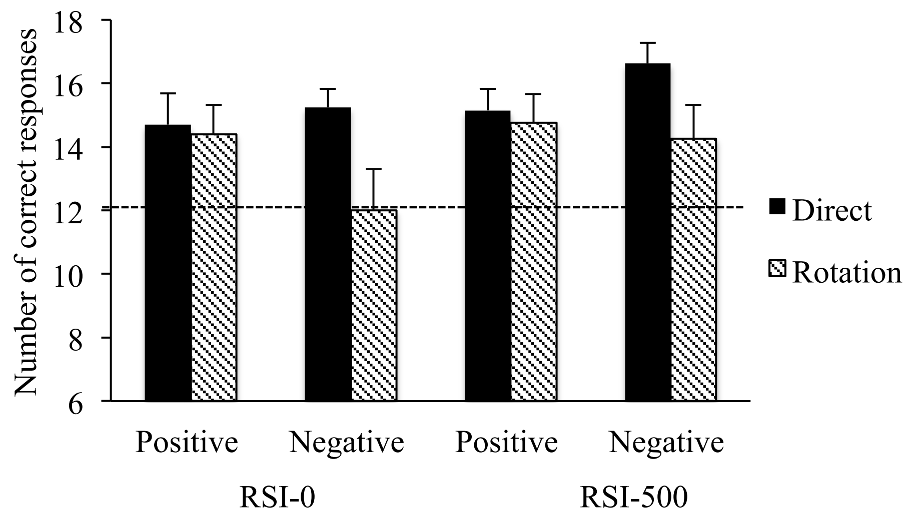

50
40
30
20
10
Mean RT difference score
RSI-0
RSI-500
Positive mood
Negative mood

Figure 4.



Number of correct responses
18
16
14
12
10
8
6
Direct
Rotation
Positive
Negative
Positive
Negative
RSI-0
RSI-500

Figure 5.