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Cognitive Factors in Evaluative Conditioning: The Role of Attention, Working Memory, and Contingency Appraisal

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Für meine Eltern und meinen Bruder

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Summary

In evaluative conditioning, the liking of a stimulus (the conditioned stimulus; CS) is being changed by pairing it with another either liked or disliked stimulus (the unconditioned stimulus; US). In terms of classical Pavlovian conditioning, the shift in the evaluative response can be referred to as a conditioned response. In the last two decades, there has been a great deal of research on whether this type of Pavlovian conditioning depends on controlled (conscious) processes, and particularly the participants' explicit knowledge about the stimulus pairings (contingency awareness). The empirical evidence on the (causal) role of contingency awareness in evaluative conditioning, however, is rather inconsistent. Whereas some studies found conditioning effects in the absence of contingency knowledge, others reported the effect to be restricted to contingency-aware participants. Most researchers refer to contingency knowledge as the recognition of CS-US pairings in a test after conditioning. The contingency recognition performance is thus expected to depend on several cognitive resources like attention and working memory. Only a few studies separately addressed the role of these cognitive factors in the acquisition awareness and evaluative conditioning. Furthermore, the propositional knowledge about the CS-US contingency may be more or less sophisticated. In addition to merely memorizing the stimulus pairings (contiguities), a participant might, for example, learn something about the statistical contingency between stimuli, as well. The effects of these cognitive factors on evaluative learning was investigated in the experiments of this dissertation. A model describing the relation between different propositional-learning processes that may influence the acquisition of contingency knowledge and evaluative conditioning is presented in the synopsis. The thesis comprises three manuscripts that are reporting five experiments in total on the impact of attention, working memory and propositional knowledge about the CS-US contingencies (contingency judgments) on the occurrence and the magnitude of evaluative conditioning.

In manuscript A, an experiment is reported ($N = 109$) that investigated the

kind of attention required in evaluative learning. Particularly, it was tested whether attention, rather than contingency awareness, is sufficient for evaluative conditioning to occur. In principle, attention can be focused either on the stimuli (the CS and the US) or on the contingency between the stimuli. Since the acquisition of contingency awareness might require a focus on the CS-US contingency, it would be interesting to see whether evaluative conditioning occurs if attention is paid to the stimuli but not to the contingencies. Therefore, three secondary tasks were implemented during conditioning in which the focus of attention was either directed to the stimulus contingencies, diverted completely from the stimuli, or diverted selectively only from the contingencies while maintaining a stimulus focus. Evaluative conditioning effects occurred only in those participants who attended the CS-US contingencies, but not when attention was diverted from the stimuli or from the contingencies. These results show that mere attention is not sufficient for evaluative conditioning to occur, if attention is diverted selectively from the CS-US contingencies. Since a contingency focus is assumed to be essential for the acquisition of contingency awareness, the results are in line with the assumption that evaluative conditioning relies on the participants' CS-US awareness during the acquisition.

In addition to requiring a specific form of attention, the acquisition of contingency knowledge is assumed to depend on working memory resources being available during the exposure to the CS-US pairings. In a series of three experiments ($N = 109$) reported in manuscript B, working memory capacity was manipulated during evaluative conditioning by means of phonological distraction. Particularly, in a verbal conditioning paradigm, the encoding of the CS-US contingencies (pairs of words) was disrupted by the playback of irrelevant speech which is assumed to gain automatic access to the same working memory module. Both, the processing and the production of irrelevant speech were shown to reduce both contingency memory and the magnitude of evaluative conditioning. These results imply that evaluative learning requires working memory resources, and they challenge the assumption that evaluative conditioning relies on automatic processes. However, the conditioning effect was not restricted to participants who were able to recall the CS-US contingencies in these experiments. Thus, though working memory may be important during conditioning in order to encode the CS-US contingencies, evaluative learning does not necessarily depend on the acquisition of long-term knowledge about the contingencies.

Manuscript C is concerned with the content of the contingency knowledge. According to the propositional account, evaluative conditioning is assumed to rely on the formation and evaluation of propositional knowledge about the predictive relation between CS and US. Thus, stronger evaluative conditioning effects may be expected if the participants perceive a strong statistical CS-US contingency than if they perceive a weak contingency. In the experiment reported in manuscript C (N = 31), the evaluative conditioning procedure was combined with a contingency learning paradigm requiring the participants to simultaneously judge the contingencies of four CS-US pairings. The subjective appraisal of contingency was manipulated by varying (a) the objective CS-US contingency and (b) the density of the US which is known to bias contingency judgments (the outcome density effect). This method allows to modulate propositional knowledge about the contingency independently of objective values of contingency during the acquisition of evaluative conditioning. Indeed, contingencies were judged to be stronger in case of low US density irrespective of the level of the objective contingency. More importantly, comparable effects of evaluative conditioning occurred with low and with high objective contingency, but the magnitude of conditioning increased with subjective contingency judgments. These results indicate that evaluative conditioning is sensitive to propositional knowledge about the CS-US relations (i.e. contingency judgments). Evaluative conditioning appears to (a) depend on contingency awareness and (b) vary with subjective beliefs about the CS-US contingency. This result is in line with the propositional account of evaluative conditioning.

Taken together, the results show (a) that evaluative conditioning depends on those cognitive resources (i.e. attention and working memory) which enable the acquisition of contingency knowledge and (b) that propositional knowledge modulates the magnitude of the conditioning effect. It is difficult to explain these findings by referring to evaluative conditioning as an automatic process of association formation. Rather, the results imply that propositional learning about the CS-US contingencies is involved in the acquisition of evaluative responses. This form of affective-evaluative learning was shown to require a specific focus of attention (a contingency focus) as well as working memory resources to be available during acquisition. Furthermore, the liking of a CS seems change as a function of the subjective appraisal of the statistical CS-US contingency.

Zusammenfassung

Die subjektive Bewertung eines Reizes kann sich dadurch verändern, dass man den Reiz (konditionierter Stimulus; CS) mit einem entweder positiven oder negativen Reiz (unkonditionierter Stimulus; US) paart. Diesen Effekt bezeichnet man als evaluatives Konditionieren, wobei sich - analog zum klassischen Konditionieren - die konditionierte Reaktion auf die evaluativen Veränderungen bezieht. In den letzten 20 Jahren beschäftigten sich zahlreiche Untersuchungen mit der Frage, ob diese Form assoziativen Lernens von kontrollierten (bewussten) Prozessen abhängt. Besonders widersprüchlich sind die Ergebnisse hierbei in Bezug auf die Frage, ob evaluatives Konditionieren darauf beruht, dass der Zusammenhang zwischen CS und US bewusst erkannt wird (Kontingenz-Awareness). Während einige Untersuchungen zeigen, dass evaluatives Konditionieren auch ohne Kontingenz-Awareness auftreten kann, berichteten andere, dass ein Konditionierungseffekt nur bei Probanden auftrat, die sich der Kontingenzen bewusst waren. Da sich die Kontingenz-Awareness auf das explizite Erinnern des CS-US Zusammenhangs bezieht, sollte sie von kognitiven Faktoren, insbesondere von einem bestimmten Aufmerksamkeitsfokus und der Arbeitsgedächtnis während der Konditionierung, abhängen. Neben dem bloßen Erinnern von Stimulus-Paarungen (Kontiguität) kann sich das propositionale Wissen eines Probanden über die Beziehung zwischen CS und US auch auf den genaueren statistischen Zusammenhang zwischen CS und US (Kontingenz) beziehen. In der Synopse wird ein Rahmenmodell vorgestellt, in dem die vermuteten Beziehungen zwischen den verschiedenen kognitiven Faktoren propositionalen Lernens und der Entstehung von Kontingenz-Awareness und evaluativem Konditionieren dargestellt sind. Die vorliegende Arbeit umfasst drei Manuskripte, in denen fünf Experimente beschrieben werden. Dabei wurde (a) die selektive Aufmerksamkeit, (b) die Arbeitsgedächtniskapazität und (c) das propositionale Wissen über die Stimuluszusammenhänge (Kontingenz-Urteile) während der evaluativen Konditionierung manipuliert. Gemessen wurden jeweils das Ausmaß des Konditionierungseffektes sowie die Kontingenz-Awareness.

In einem in Manuskript A beschriebenen Experiment ($N = 109$) wurde die Rolle des spezifischen Aufmerksamkeitsfokus während der Konditionierung untersucht. Dabei wurde die Hypothese überprüft, ob Effekte evaluativer Konditionierung auch ohne Kontingenz-Awareness auftreten, wenn die Aufmerksamkeit auf die relevanten Stimuli (CS und US) gerichtet wird. Dazu wurde der Fokus der Aufmerksamkeit während der Konditionierung in drei experimentellen Bedingungen entweder (a) auf die CS-US-Kontingenzen gerichtet (Kontingenz-Fokus), (b) vollständig abgelenkt oder (c) selektiv nur von den CS-US Kontingenzen abgelenkt während sie auf die Stimuli selbst gelenkt wurde (Stimulus-Fokus). Falls bloße Aufmerksamkeit hinreichend ist, dann sollten sich auch in der letzten Gruppe Effekte evaluativen Konditionierens zeigen. Die Ergebnisse zeigen aber, dass ein Effekt evaluativen Konditionierens trotz eines Stimulus-Fokus nicht auftritt, wenn die Aufmerksamkeit selektiv von der Kontingenz zwischen den Stimuli abgelenkt wird. Konditionierungseffekte zeigten sich nur bei Probanden, die ihre Aufmerksamkeit auf die CS-US Kontingenzen richteten. Wichtiger als bloße Aufmerksamkeit scheint also ein spezifischer Kontingenz-Fokus zu sein. Außerdem traten Konditionierungseffekte nur bei Probanden auf, die sich der Kontingenzen bewusst waren. Die Ergebnisse unterstützen daher die Annahme, dass evaluatives Konditionieren auf bewusstem Wissen über die Stimulus-Kontingenzen beruht.

Neben der Aufmerksamkeit, sollte die verfügbare Arbeitsgedächtniskapazität während der Konditionierung ein weiterer limitierender kognitiver Faktor bei der Entstehung von Kontingenz-Awareness sein. Darum werden in Manuskript B drei Experimente zur Rolle des Arbeitsgedächtnisses beim evaluativen Konditionieren beschrieben ($N = 109$). In diesen wurde die verfügbare Arbeitsgedächtniskapazität experimentell reduziert, indem während der Konditionierung mit verbalen Stimuli irrelevante Sprache wiedergegeben wurde. Hierdurch sollte die Enkodierung von CS-US Wortpaaren im Arbeitsgedächtnis gestört werden, da die irrelevante Sprache mit den CS-US-Paaren um den Zugang zum phonologischen Speicher konkurriert. Irrelevante Sprache sollte also mit geringerer Kontingenz-Awareness einhergehen. Tatsächlich zeigte sich, dass sowohl die Wiedergabe als auch das aktive Produzieren irrelevanter Sprache zu einer Störung des Kontingenz-Gedächtnisses und zu einer Beeinträchtigung der evaluativen Konditionierung führt. Die erwarteten Bewertungsveränderungen traten nur auf, wenn die Probanden während der Konditionierung über ausreichend Arbeitsgedächtniskapazität verfügten. In diesen Experimenten trat evaluatives Konditionieren allerdings nicht nur bei Probanden auf, welche sich nach der Konditionierung an die CS-US-Paarungen erinnerten. Obwohl ausreichend Arbeitsgedächtniskapazität benötigt wird um die CS-US-Kontingenzen während der Konditionierung zu enkodieren, scheint der Erwerb von Langzeit-Wissen über die CS-US-Zusammenhänge also nicht entscheidend zu sein.

Manuskript C beschäftigt sich mit dem Inhalt des propositionalen Wissens beim evaluativen Konditionieren. Nach dem propositionalen Erklärungsansatz beruht evaluatives Konditionieren auf dem Erwerb und der Beurteilung von propositionalem Wissen über die CS-US Kontingenz. Hierbei könnte ein Proband auch über Wissen bezüglich der Stärke des prädiktiv-statistischen Zusammenhangs zwischen CS und US (Kontingenz) verfügen. Man könnte also größere Konditionierungseffekte erwarten, je höher die CS-US Kontingenz subjektiv eingeschätzt wird. Um dies zu untersuchen wurde in dem in Manuskript C beschriebenen Experiment ($N = 31$) die subjektive Wahrnehmung der CS-US Kontingenz experimentell manipuliert. Dazu wurde (a) die objektive CS-US Kontingenz und (b) die Auftretensdichte der affektiven Reize (US) variiert. Die Dichte der US sollte sich unabhängig von der objektiven CS-US Kontingenz auf die subjektiven Einstufungen der Kontingenz auswirken (Outcome density effect). Die Aufgabe der Probanden war es, die statistischen Zusammenhänge von mehreren CS-US-Paaren während der evaluativen Konditionierung einzustufen (Kontingenzurteile). Wenn evaluatives Konditionieren von propositionalem Wissens über die CS-US Kontingenz abhängt, dann sollten hohe Kontingenzurteile mit größeren Konditionierungseffekten einhergehen. Obwohl die Probanden Variationen in der objektiven Kontingenz bemerkten, beurteilten sie die Kontingenzen als stärker, wenn der jeweilige US insgesamt seltener auftrat. Es zeigten sich allerdings ähnlich große Konditionierungseffekte bei hoher wie bei niedriger objektiver Kontingenz. Unabhängig davon konnten stärkere Konditionierungseffekte nachgewiesen werden, je höher die CS-US Kontingenz subjektiv eingestuft wurde. Die Ergebnisse suggerieren also, dass evaluatives Konditionieren vielmehr durch die subjektive Wahrnehmung statistischer Kontingenz (propositionales Wissen) als durch die Variation der objektiven Kontingenzen beeinflusst wird.

Insgesamt sprechen die Ergebnisse dafür, dass evaluatives Konditionieren von kognitiven Ressourcen abhängt, die zu Kontingenz-Awareness führen (Aufmerksamkeit und Arbeitsgedächtnis). Zudem zeigte sich, dass stärkere Bewertungsveränderungen mit höheren CS-US Kontingenzurteilen einhergehen. Es ist schwierig, diese Befunde mit Theorien zu erklären, die annehmen, dass evaluatives Konditionieren auf (unbewusster) automatischer Assoziationsbildung beruht. Stattdessen sprechen die Befunde dafür, dass kognitive Faktoren und (bewusstes) propositionales Wissen über den Zusammenhang zwischen CS und US an der Entstehung evaluativen Konditionierens beteiligt sind. Während der Darbietung der CS-US Paare wird dazu ein bestimmter Fokus der Aufmerksamkeit (Kontingenz-Fokus) und ausreichend Arbeitsgedächtniskapazität benötigt. Außerdem scheint sich die Bewertung eines CS umso mehr zu verändern, je stärker der statistische Zusammenhang zwischen CS und US subjektiv eingeschätzt wird.

Contents

Acknowledgment 4

Summary 5

Zusammenfassung 8

List of Figures 16

List of Tables 17

List of Original Manuscripts 18

I. Synopsis 19

1. Theoretical Background 20

- 1.1. Introduction 20
- 1.2. Evaluative conditioning 21
  - 1.2.1. History of EC research 22
  - 1.2.2. Functional characteristics of EC 23
- 1.3. The contingency-awareness issue 25
  - 1.3.1. Contingency awareness and Pavlovian conditioning 25
  - 1.3.2. The controversy about the role of contingency awareness in EC 27
- 1.4. Accounts of evaluative conditioning 30
  - 1.4.1. The holistic account 30
  - 1.4.2. The referential-learning account 31
  - 1.4.3. The concept categorization account 32
  - 1.4.4. The implicit misattribution account 32
  - 1.4.5. The propositional account 33

1.5. Research questions 33
1.5.1. Theoretical framework 33
1.5.2. Relations between the manuscripts 37

2. Outline of the thesis 40
2.1. Manuscript A - “Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus” 40
2.1.1. Purpose of the study 40
2.1.2. Method 41
2.1.3. Results and Discussion 42
2.2. Manuscript B - “Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning” 42
2.2.1. Purpose of the study 42
2.2.2. Method 43
2.2.3. Results and Discussion 44
2.3. Manuscript C - “Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning” 45
2.3.1. Purpose of the study 45
2.3.2. Method 46
2.3.3. Results and Discussion 46

3. General discussion and conclusions 48
3.1. Summary of results 48
3.2. Theoretical significance 52
3.3. Practical implications 54
3.4. Limitations and future perspectives 56

4. References 58

II. Original Manuscripts 70

5. Manuscript A 71
Abstract 71

5.1. Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus 72
5.2. Method 75
5.2.1. Participants 75
5.2.2. Stimuli and Apparatus 75
5.2.3. Procedure 76
5.3. Results 77
5.3.1. Manipulation Check and Contingency Awareness 78
5.3.2. EC effects 78
5.3.3. Contingency Awareness and EC 79
5.4. Discussion 80
5.5. References 83

6. Manuscript B **88**
Abstract 88
6.1. Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning 89
6.2. Experiment 1 93
6.2.1. Method 93
6.2.2. Results 95
6.2.3. Discussion 97
6.3. Experiment 2 99
6.3.1. Method 99
6.3.2. Results 100
6.3.3. Discussion 102
6.4. Experiment 3 103
6.4.1. Method 104
6.4.2. Results 105
6.4.3. Discussion 107
6.5. General Discussion 108
6.6. References 111

7. Manuscript C **117**
Abstract 117

7.1. Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning 118
7.2. Method 122
7.2.1. Participants 122
7.2.2. Materials and apparatus 122
7.2.3. Experimental design 123
7.2.4. Procedure 123
7.3. Results 126
7.3.1. Contingency awareness 126
7.3.2. Contingency judgments 126
7.3.3. Evaluative Ratings 128
7.3.4. Relation between contingency judgments and EC 129
7.4. Discussion 130
7.5. References 134

III. Appendix 140

A. Original instructions (German) 141
A.1. Instructions belonging to manuscript A 141
A.2. Instructions belonging to manuscript B 143
A.3. Instructions belonging to manuscript C 145

Index of authors 148

Wissenschaftlicher Werdegang 153

Eidesstattliche Erklärung 154

List of Figures

1.1. Schematic illustration of ‘strict’ and ‘weak’ forms of single-process models (A1 and A2), and dual-process models (B), according to Lovibond & Shanks (2002). 35
1.2. The relations between the three manuscripts and a schematic illustration of the assumed steps (cognitive factors) in propositional learning (gray boxes). Each manuscript addresses the effect of one well-defined process on EC, and its relation with the acquisition of CS-US contingency knowledge. Further explanations are made in the text. 36

6.1. Evaluative ratings of non-words that were paired with positive or negative words either in silence or under conditions of irrelevant speech or articulatory suppression (experiment 1). 96
6.2. Evaluative ratings of non-words that were paired with liked or disliked non-words either in silence or under conditions of irrelevant speech or articulatory suppression (experiment 2). 101
6.3. Evaluative ratings of non-words that were paired with liked or disliked non-words under different irrelevant sound conditions (experiment 3). 106

7.1. Contingency judgments of CS-US pairings as a function of US density and contingency. 127
7.2. Evaluative ratings in the baseline phase (pre) and after conditioning (post) as a function of US density and contingency. 129

List of Tables

1.1. Original Manuscripts. 39

3.1. Summary of the effect sizes of EC in the studies reported in manuscripts A, B, and C. 51

5.1. Mean contingency awareness and mean subjective rating differences (EC) of CS pictures that were paired with a liked or a disliked US (standard deviations in parentheses). 79

6.1. Contingency memory in experiment 1 (in percentage correct, standard deviations in parentheses). 97

6.2. Contingency memory (in percent correct) and evaluative rating differences of non-recognized and recognized CS-US pairings in experiment 2 (standard deviations in parentheses). 102

6.3. Contingency memory (in percent correct) and evaluative rating differences for recognized and non-recognized pairings in experiment 3 (standard deviations in parentheses). 107

7.1. A 2 $\times$ 2 matrix representing the four types of events in contingency learning (corresponding events in a conditioning setting are written in parentheses). The frequencies of the four possible combinations are represented by the letters a, b, c, and d. 120

7.2. The values of b, c and d in the contingency matrix for the eight CS-US pairings and the resulting values of ΔP, US density and CS density within the two learning blocks. 124

7.3. Response criteria c for four arbitrary category boundaries along the (0-100) contingency rating scale. 128

List of Original Manuscripts

This doctoral thesis is based on three original articles (either in press or submitted). They will be referred to in the text by their respective capital letters.

A Kattner, F. (in press). Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus. *Cognition and Emotion*. doi: 10.1080/02699931.2011.565036 ....p. 71

B Kattner, F. & Ellermeier, W. (2011). *Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning*. Manuscript submitted for publication. ....p. 88

C Kattner, F. & Ellermeier, W. (in press). Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning. *Experimental Psychology*. doi: 10.1027/1618-3169/a000108 ....p. 117

Part I.

Synopsis

1. Theoretical Background

1.1. Introduction

Any form of cognition or behavior involves an individual history of *learning* (Shanks, 1995) which can be defined as relatively permanent changes in apparent or latent behavior that result from experience (or reinforced practice; Kimble, 1967). Learning allows an organism to understand about the (causal) structure of the physical or social environment, and it is necessary to respond in apposite ways. In order to approach food or to avoid threats, for instance, an organism has to learn something about the predictive relationship between the occurrence of certain cues (e.g., a paricular smell) and their consequences (outcomes like food or threat).

According to an associative view of learning, the acquisition of knowledge is based on connections between sensory experiences. Contemporary theories of associative learning treat Pavlovian conditioning (Pavlov, 1927) as a general principle of learning: An organism learns to associate a neutral stimulus with a significant event and eventually it shows a conditioned response whenever the previously neutral stimulus occurs. Thus, learning refers to the acquisition of representations of stimulus relations, and it can be distinguished from behavior (Lachnit, 1993, p. 30). However, depending on their professional perspective, psychologists differ with respect to what exactly is meant by the term 'learning'. Behaviorists refer to learning as the emergence of new responses (e.g., Watson, 1913). Thus, the dog in a Pavlovian conditioning setting is considered to have learned something only if he shows a new response when being confronted with a bell: he salivates. By contrast, a more cognitive definition does not restrict learning to observable behavior, but rather to any 'process that allows a transition from one mental state to another' (Shanks, 1995). In addition to behavioral responses, learning can thus also involve the acquisition of knowledge (e.g., about the spatial or temporal relations between stimuli), preferences or attitudes that do not necessarily lead to overt behavior. The Pavlovian dog may thus have learned something about the relationship between the bell and food already before he starts salivating: he might have acquired an expectation about the delivery of food. Nevertheless, this cognitive definition has its shortcomings, as well (e.g., with regard to the distinction between learning and forgetting; Shanks, 1995).

Related to these divergent conceptions of learning, Pavlovian conditioning procedures differ with regard to the conditioned responses that are addressed. The responses may consist in overt behavior (e.g., approach or avoidance) or autonomic responses (e.g., skin conductance responses), as well as in causality judgments or attitude measures (at least in human subjects). It has been argued that human behavior is determined to a large extent by attitudes, and particularly by subjective likes and disliked (e.g., Martin & Levey, 1978). Since most of these attitudes are not innate but have been learned individually (Rozin & Millman, 1987), several studies have been concerned with the acquisition and with the change of likes and dislikes by conditioning in the last 35 years (see De Houwer, Thomas, & Baeyens, 2001). This form of affective-evaluative learning is outlined in the next section.

1.2. Evaluative conditioning

Evaluative conditioning (EC) refers to a form of learning in which the liking of a stimulus (the conditioned stimulus; CS) changes as a result of repeatedly pairing it with either a liked or a disliked stimulus (the unconditioned stimulus; US). Thus, the main procedural difference between EC and other forms of Pavlovian conditioning is the fact that the conditioned response is a change in the subjective liking of a stimulus (the evaluative response) rather than in behavioral or autonomic responses (see De Houwer, 2007). Typically, the evaluation of the CS changes in the direction of the valence of the US (e.g., Levey & Martin, 1975), but evaluative contrast effects (e.g., Hammerl & Fulcher, 2005) can be seen as particular instances of evaluative learning, as well (see De Houwer et al., 2001; De Houwer, Baeyens, & Field, 2005; Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010; Martin & Levey, 1978, for reviews and a meta-analysis on EC).

1.2.1. History of EC research

Early demonstrations of EC stem from Razran (1940) who paired political slogans (the CS) with either a free lunch or unpleasant odors (the US). Afterwards, slogans that were associated with the free lunch were evaluated more positively than those that were paired with the odors. Also verbal conditioning at which attitudes towards neutral words (e.g., nonsense words) are being changed by paired them with either positively or negatively valenced words (C. K. Staats & Staats, 1957; A. W. Staats & Staats, 1958) can be seen as early evidence of EC (see Jaanus, Defares, & Zwaan, 1990, for a review on verbal conditioning).

A widely used paradigm of modern EC research (the so-called picture-picture paradigm) has been introduced by Levey and Martin (1975) and elaborated by Baeyens, Eelen, and Van den Bergh (1990). It consists of a baseline rating phase, an acquisition phase, and a test rating phase. Based on the baseline ratings, a set of pictures is sorted into liked, disliked, and neutral pictures. In the subsequent acquisition phase, previously neutral pictures (CSs) are presented together with either liked, disliked, or other neutral pictures (USs). Subsequent post-ratings of the pictures revealed that the valence of the CSs that were paired with liked or disliked USs had changed in the direction of the valence of the US (CS-rating differences between baseline and test phase can be used as a measure of EC). In addition to these verbal report measures, however, EC effects have also been reported with indirect measures of evaluative responses, e.g., by means of affective priming (Hermans, Vansteenwegen, Crombez, Baeyens, & Eelen, 2002; Dawson, Rissling, Schell, & Wilcox, 2007).

Since these early demonstrations of EC, many replications utilizing the picture-picture paradigm have been reported (e.g., Baeyens, Crombez, Van den Bergh, & Eelen, 1988; De Houwer, Baeyens, Vansteenwegen, & Eelen, 2000; Hammerl & Grabitz, 1993, 1996). Further, EC was shown to occur with haptic (e.g., Hammerl & Grabitz, 2000; Fulcher & Hammerl, 2001b), or taste/flavor stimuli (Baeyens, Eelen, Van den Bergh, & Crombez, 1990; Dickinson & Brown, 2007; Dwyer, Jarratt, & Dick, 2007), and there have been demonstrations of cross-modal EC effects (e.g., with Greek letters and music, or with faces and odors; Eifert, Craill, Carey, & O'Connor, 1988; Todrank, Byrnes, Wrzesniewski, & Rozin, 1995). The auditory modality of the CS, however, has been neglected in previous studies. In order to extend the scope of EC, a secondary objective of the study reported in manuscript C (compare Table 1.1) was to show whether EC effects occur with auditory CSs.

EC studies have been conducted within various domains of research, including learning psychology (Baeyens, Eelen, & Van den Bergh, 1990), social psychology (e.g., Olson & Fazio, 2001), clinical psychology (e.g., Hermans et al., 2004), neuroscience (e.g., Coppens et al., 2006), consumer science (e.g., Allen & Janiszewski, 1989; Stuart, Shimp, & Engle, 1987; Sweldens, 2009), and nutrition research (e.g., Bernstein & Webster, 1980). Furthermore, applications of EC can be found in several domains, as well. Classical conditioning of attitudes towards brands and products has become a unique field of research in advertising and consumer science (Till & Priluck, 2000). Shimp, Stuart, and Engle (1991), for instance, have shown that attitudes towards unknown and moderately known brands can be changed by means of conditioning if the participants are aware of the relationship between the brands and the USs. EC has also been applied to clinical psychology, particularly with respect to depression and phobias. In an evaluative counterconditioning procedure, Eifert et al. (1988) showed that fear reactions towards spiders or snakes can by reduced by presenting the aversive stimuli together with pleasant stimuli, i.e. music.

It is surprising, however, that applications of EC to advertising and clinical psychology often do not make a distinction between EC and classical conditioning (Walther, Nagengast, & Trasselli, 2005). Although EC and other forms of Pavlovian conditioning have a lot in common on a procedural level, there appear to be differences on the process level (see De Houwer et al., 2001). Functional discrepancies between EC and Pavlovian conditioning have been reported particularly with regard to the effects of *CS-US contingency*, *extinction trials* (CS only trials after conditioning), and *contingency awareness* on the occurrence of conditioned responses. Some of these findings implying that EC is a distinct form of Pavlovian conditioning are described next.

1.2.2. Functional characteristics of EC

In Pavlovian conditioning, it has been shown that contiguous CS-US pairings do not produce a conditioned response if the CS does not hold any predictive information about the occurrence of the US (Rescorla, 1968). More precisely, conditioning only occurs if the conditional probability of the US in the presence of the CS differs from the conditional probability of the US in the absence of the CS (the difference between these probabilities is a common measure of *contingency*, see Allan, 1980). Similarly, post-conditioning presentations of the CS in the absence of the US (CS-only) will gradually eliminate the CS's ability to elicit a conditioned response (*extinction*, e.g., Hamm & Vaitl, 1996; Hugdahl & Öhman, 1977). Since extinction trials reduce the CS-US contingency, the occurrence of this phenomenon also implies that Pavlovian conditioning is susceptible to contingency. EC, however, has been shown to occur at various levels of and even in the absence of statistical contingency (Baeyens, Hermans, & Eelen, 1993), and the presentation of CS-only trials after conditioning were repeatedly shown to not affect the acquired evaluative responses (Baeyens et al., 1988; Díaz, Ruiz, & Baeyens, 2005; Dwyer et al., 2007).

Many researchers thus concluded that EC is resistant to extinction and does not rely on statistical CS-US contingency (e.g., Baeyens, Eelen, & Crombez, 1995; De Houwer et al., 2000). A dissociation between EC and Pavlovian conditioning with respect to contingency and extinction is important also with regard to practical applications. Based on the observation that patients sometimes do not benefit from an exposure therapy (which is based on extinction), Rachman (1985) proposed that EC might be involved in the genesis of anxiety disorders. Though the conditioned physiological reactions disappear after an exposure therapy (due to classical conditioning), the patient's experienced emotions with respect to the phobic stimuli might persist due to the resistance to extinction in EC. Indeed, a recent conditioning experiment with pictures (CSs) and electric shocks (USs) has shown that though the conditioned physiological reactions decreased, the acquired evaluative reactions did not change after a couple of extinction trials (Vansteenwegen, Francken, Vervliet, De Clercq, & Eelen, 2006).

There is another debate on whether EC - like Pavlovian conditioning - is affected by *cue competition* which refers to the phenomenon that the acquisition of a conditioned response is influenced by the presence of other stimuli being associated with the US. Pairing two stimuli A and B with a US, for instance, results in a reduced conditioned response towards B when A had been paired with the same US by itself before (*blocking*; Kamin, 1968, 1969). In contrast to Pavlovian conditioning, EC seems to be insensitive to blocking (Beckers, De Viqo, & Baeyens, 2009; Dwyer et al., 2007; Lipp, Neumann, & Mason, 2001, but see Purkis & Lipp, in press).

One of the biggest controversies in EC research, however, concerns the role of *contingency awareness* and attentional resources. This issue is addressed in the next section.

1.3. The contingency-awareness issue

1.3.1. Contingency awareness and Pavlovian conditioning

Early behaviorist conceptions of associative learning assumed Pavlovian conditioning to result from unconscious, automatic association-formation processes (e.g., Thorndike, 1911; Watson, 1913). However, there are three types of empirical evidence casting doubt on this assumption. First, many studies have shown that autonomic conditioning only occurs in subjects who are aware of the contingencies between CSs and USs, whether the autonomic measure is skin conductance (e.g., Hamm & Vaitl, 1996; Marinkovic, Schell, & Dawson, 1989), heart rate (Hamm & Vaitl, 1996), or the modulation of the startle blink reflex to loud auditory stimuli (Purkis & Lipp, 2001). Second, it has been found that conditioned responses do not start to appear until a subject is able to report the CS-US contingencies (Purkis & Lipp, 2001). Lovibond (1992) has shown that the level of skin conductance and US expectancy are highly correlated ($r = .44$) across conditioning trials within subjects who were classified as contingency-aware (again, unaware subjects did not show conditioning). Third, having the subjects' attention diverted by additional distraction tasks being applied during conditioning has been shown to reduce both contingency awareness and the extent of conditioned electro-dermal responses (Dawson, 1970; Dawson & Biferno, 1973). Several reviews of Pavlovian conditioning thus came to the conclusion that conditioned responses are closely associated with explicit contingency knowledge or US expectancies, and that there is no conditioning in the absence of contingency awareness (Brewer, 1974; Davey, 1987; Dawson & Schell, 1985, 1987; Lovibond & Shanks, 2002; Mitchell, De Houwer, & Lovibond, 2009; Öhman, 1979). Furthermore, Pavlovian conditioning is supposed not to occur before the subject has reached contingency awareness. Some authors even inferred that contingency awareness is necessary (Dawson & Furedy, 1976) or even necessary and sufficient for autonomic conditioning to occur (Brewer, 1974).

In line with these findings, well-established theories of associative learning (e.g., Rescorla & Wagner, 1972) propose controlled processes (i.e. US expectancy, contingency awareness) to be involved in the formation of an associative connection between the representation of CS and the representation of the US which allow the organism to make predictions about significant events in the environment (i.e. the appearance of the US). Furthermore, many theories of associative learning (e.g., Mackintosh, 1975; Pearce & Hall, 1980)[1], assume conditioning to be sensitive to the availability of attentional resources which can be seen as a prerequisite of contingency awareness.

There are only a few - and controversially discussed - studies showing Pavlovian conditioning of fear-relevant stimuli in the in the absence of US expectancy or after it has disappeared due to extinction procedures (Hugdahl & Öhman, 1977; Schell, Dawson, & Marinkovic, 1991; Dawson, Schell, & Banis, 1986). These findings somehow support the assumption that particular associations involving fear-relevant CSs and biologically significant aversive outcomes are formed by rather primitive conditioning processes that do not require awareness (Seligman, 1971). Nevertheless, due to the many failures in producing learning or memory effects with subliminally presented stimuli, it would be premature to conclude that learning occurs if participants are unaware at the time of exposure (Shanks & St. John, 1994).

In the end, Mitchell et al. (2009) identified two learning paradigms that provide some evidence for unaware conditioning: (a) Perruchet's paradigm yielding a dissociation between US expectancy and conditioning, and (b) a couple of EC studies (these will be mentioned in the next section). By comparing the responses after successive conditioning trials (CS-US) with those after successive CS-only trials, Perruchet (1985) found the conditioned eye-blink responses to decrease with an increase of the participants' US expectancy. Whereas the conditioned eye-blink responses were most likely after a run of CS-US trials and decreased with the number of non-reinforced trials occurring, the expectancy ratings were subject to the gambler's fallacy. That is, the participants expected a US to occur particularly after a run of CS-only trials but not after a run of CS-US trials (see Clark & Squire, 1998; Clark, Manns, & Squire, 2001; Perruchet, Cleeremans, & Destrebecqz, 2006, for replications). Since recent CS-US trials reduced the participants' US expectancy but increased the associative strength, these studies suggest a dissociation between conditioning and awareness.

The rather controversial data on the relation between of contingency awareness and EC will be considered in the next section.

[1]These learning models differ basically with respect to the assumed mechanism determining whether a stimulus receives attention or not. Whereas Mackintosh (1975) suggested that a stimulus receives attention when it occurs contingently with a relevant outcome (the US), the Pearce-Hall theory (Pearce & Hall, 1980) assumes that attention will be paid primarily to stimuli with a low associative strength rather than to stimuli that accurately predict the outcome, already.

1.3.2. The controversy about the role of contingency awareness in EC

In early verbal conditioning studies (C. K. Staats & Staats, 1957) and in Levey and Martin's (1975) paradigmatic study on EC, changes in the liking of words or postcards, respectively, were found in subjects who were unable to recall the CS-US contingencies. Similarly, more recent results imply that contingency awareness and EC are unrelated (e.g., Baeyens, Eelen, & Van den Bergh, 1990; Baeyens et al., 1993; Gast & Rothermund, 2011; Olson & Fazio, 2001), and EC effects have been reported occasionally even in the absence of contingency awareness or when it had been reduced experimentally (Dickinson & Brown, 2007; Fulcher & Hammerl, 2001b; Hammerl & Grabitz, 2000; Hammerl & Fulcher, 2005; Walther & Nagengast, 2006). Fulcher and Hammerl (2001b), for instance, found EC to occur only when the participants' degree of contingency awareness has been reduced by means of a distractor task that diverted attention during conditioning (see Walther, 2002, for a related finding). Particularly, studies showing EC with subliminally presented USs provide a strong argument for the existence of unaware EC because it is extremely unlikely that subjects acquired awareness of the CS-US contingency (De Houwer, Baeyens, & Eelen, 1994; De Houwer, Baeyens, & Hendrickx, 1997; Field & Moore, 2005; Fulcher & Hammerl, 2001b). By contrast, however, other studies have shown that EC like other forms of conditioning depends on the availability of attentional resources (Field & Moore, 2005; Pleyers, Corneille, Yzerbyt, & Luminet, 2009) and on the acquisition of contingency awareness (e.g., Dawson et al., 2007; Pleyers, Corneille, Luminet, & Yzerbyt, 2007; Purkis & Lipp, 2001; Stahl & Unkelbach, 2009; Stahl, Unkelbach, & Corneille, 2009). In these studies, EC effects were found only in participants who were classified as being aware of the CS-US contingencies and only for those pairings that a participant was aware of (Pleyers et al., 2007).

Taken together, there are several studies reporting evaluative learning in the absence of contingency awareness (see De Houwer et al., 2001, for a review), and EC has been identified to be a conditioning procedure that has produced some of the most promising evidence for unaware associative learning (Mitchell et al., 2009). However, while reliable EC effects have been identified in unaware participants as well, a recent meta-analysis on EC reported larger conditioning effects for contingency-aware subjects and for those CS-US pairings that were memorized (Hofmann et al., 2010). Due to this inconsistency of results, the contingency-awareness issue has been referred to as the most important unsolved question in EC research (Walther & Nagengast, 2006). Particularly the question of whether contingency awareness plays a *causal* role in the acquisition of EC remains unsolved (see De Houwer, 2001; Field, 2000, 2001; Fulcher & Hammerl, 2001b; Lovibond & Shanks, 2002; Mitchell et al., 2009, for further discussions).

Many studies of EC have been criticized for their methodological shortcomings (see Lovibond & Shanks, 2002; Shanks & St. John, 1994, for critical reviews on the sensitivity of awareness measures). In EC research (which practically is restricted to human subjects), contingency awareness is typically referred to as the participants' knowledge that a specific CS has been paired with a specific US and it is often operationalized as the participant's ability to recall the CS-US relationship after conditioning (e.g., Baeyens, Eelen, & Van den Bergh, 1990)[2]. The level of contingency awareness can be measured by means of a post-conditioning recognition test developed by Baeyens, Eelen, and Van den Bergh (1990). Within this procedure, subjects have to tell the experimenter which stimuli had been paired with each other (e.g., by selecting a particular associate stimulus for each CS out of two to six probe stimuli; Fulcher & Hammerl, 2001b; Walther & Nagengast, 2006). In many studies, it was not necessary to recall a particular stimulus, but the subject was classified as aware of a CS-US contingency if he or she was able to recall either the respective US or another stimulus of the same valence as the US (e.g., Hammerl & Grabitz, 2000; Hammerl & Fulcher, 2005). These rather 'weak' criteria of contingency awareness (Davey, 1994b) have the advantage to minimize the probability of false unaware classifications and should thus be used particularly when testing the hypothesis that EC does not rely on contingency awareness. Nevertheless, a potential weakness of post-conditioning awareness measures lies in the temporal distance between encoding and recall of the stimulus pairings. The subjects might have been aware of the contingencies during the acquisition phase but have forgotten them until the test phase. Therefore, it seemed important to integrate the measurement of awareness into the acquisition phase. By comparing post-conditioning recognition

[2]In Pavlovian conditioning terminology contingency awareness is often separated from US expectancy. Whereas the first term refers to the knowledge that a particular CS predicts a particular US, the second refers to the awareness of immediate US delivery. According to Lovibond and Shanks (2002), participants are considered aware of the contingencies when they expect a particular US and when they also know why.

tests with trial-by-trial US expectancy ratings during the acquisition phase, it was shown that both measures basically produce the same results with respect to the role of contingency awareness in EC (Baeyens, Eelen, & Van den Bergh, 1990; Purkis & Lipp, 2001). The overall awareness on a post-conditioning recognition test, however, increased (from 18% to 77%) when subjects had to give concurrent estimates of awareness during the learning phase (Baeyens, Eelen, & Van den Bergh, 1990), showing that concurrent measurement have a serious impact on the acquisition of contingency awareness.

Lovibond and Shanks (2002) argue that the inability to recognize a CS-US pairing (as done by Öhman & Soares, 1993, for instance) does not mean that the participant is unaware of the contingencies. Instead they propose a less stringent test of awareness: Instead of identifying individual stimuli, participants should only have to discriminate between categories of stimuli (CS+/CS- or masked/non-masked stimuli) at a level above chance (but see Wiens & Öhman, 2002). Further, it has been argued that contingency awareness may be underestimated in many studies because awareness scores were aggregated across participants. Indeed, re-analyses suggest that conditioning effects observed in subjects who were classified as unaware due to their overall awareness score might be based on a subset of those few CS-US pairings they were aware of (e.g., Wardle, Mitchell, & Lovibond, 2007). In line with this, contingency awareness has been analyzed (or manipulated) on the level of CS-US pairings rather than on the level of participants in all the studies reported in this dissertation.

Other researchers proposed to distinguish between different types of CS-US contingency awareness. Stahl and Unkelbach (2009) and Stahl et al. (2009), demonstrated EC in participants who are unable to recall the identity of the USs that had been paired with particular CSs, if they are able to recall the valence of the respective USs. Furthermore, EC was shown to occur after a CS had been paired with a single US as well as when it had been paired with several USs of the same valence (Olson & Fazio, 2001; Stahl & Unkelbach, 2009). These results imply that awareness of US valence rather than awareness of US identity is crucial for the acquisition of EC. The particular role of valence awareness has been studied in manuscript A, as well.

Due to those empirical findings that suggest a dissociation between EC and other form of associative learning with respect the above mentioned variables, EC was considered to be a unique form of learning. Different theoretical accounts of EC are outlined in the next section.

1.4. Accounts of evaluative conditioning

Based on early demonstrations of EC (Razran, 1954; C. K. Staats & Staats, 1957; A. W. Staats & Staats, 1958), the same processes as in Pavlovian conditioning were assumed to lead to affective-evaluative transfers from the US to the CS. EC was considered to be an attitudinal version of classical conditioning that applies to affective-evaluative responses rather than to physiological or motor responses.

Due to the functional discrepancies between EC and other forms of associative learning concerning the roles of contingency, cue competition and particularly contingency awareness (e.g., Baeyens et al., 1988; Baeyens, Eelen, & Van den Bergh, 1990; Baeyens et al., 1993), it has been suggested that EC is a unique form of conditioning distinct from Pavlovian signal learning. Several alternative models have been proposed since to account for the acquisition of EC. The most important ones are introduced briefly in the following.

1.4.1. The holistic account

According to the holistic account of EC, the paired presentations of CS and US are supposed to automatically change the perception of the CS, i.e. it becomes more similar to the US. In the end, a holistic representation is formed containing elements of the CS as well as elements of the US including the valence of the US (Martin & Levey, 1978, 1994; Levey & Martin, 1975). Subsequent CS presentations are assumed to activate the whole representation, and thus automatically retrieve the evaluative response towards the US. In other words, the CS is thought to bring out its own reinforcement' (Martin & Levey, 1994, p. 301)

Contiguous co-occurrences of the CS and the US are supposed to be sufficient for EC to occur and awareness of these stimulus pairings should not be necessary. The account is in line with results showing that EC is resistant to extinction (Baeyens et al., 1988; Vansteenwegen et al., 2006), and not sensitive to statistical contingency (Baeyens et al., 1993). However, since holistic CS-US representations are formed only if both the CS and the US are presented together, the holistic account is not able to explain the occurrence of sensory preconditioning in EC (that is changes in the liking of a CS that was never paired directly with the US but only with another CS; e.g., Hammerl & Grabitz, 1996).

1.4.2. The referential-learning account

Baeyens, Eelen, Crombez, and Van den Bergh (1992) have proposed a dual-process account of Pavlovian conditioning that distinguishes between learning (a) predictive and (b) merely referential stimulus relationships. In typical instances of Pavlovian conditioning an organism is supposed to learn that the CS signalizes the prompt appearance of the US. The extent of learning is assumed to be a function of how contingently the CS-US pairings occur (e.g., Rescorla, 1988). Thus conditioning is assumed to depend not only on the number of CS-US pairings (i.e. contiguity), but on the statistical contingency between CS and US which also depends on the number of times the CS or the US is presented alone. Eventually, the organism expects the emergence of the US whenever the CS occurs. Thus, learning is supposed to depend on a certain degree of awareness concerning the CS-US relationship which is necessary to anticipate the US (Lovibond & Shanks, 2002).

By contrast, referential learning is considered as a more basic form of learning that follows a simple Hebbian learning rule only requiring parameters of contiguity and stimulus salience. The strength of the CS-US association increases whenever the stimuli co-occur, but it remains unchanged when a CS or a US is presented in isolation. After conditioning, the CS is supposed to activate the mental representation of the US without generating an expectation of the US to occur. Thus, referential learning is assumed to occur automatically and independently of awareness. This type of learning has been suggested to underly EC (Baeyens et al., 1992; Baeyens, Vansteenwegen, Hermans, & Eelen, 2001). The referential learning account can explain the observed resistance to extinction in EC (Baeyens et al., 1988; Dwyer et al., 2007), and it also predicts EC to be insensitive to contingency (Baeyens et al., 1993) and to blocking (Beckers et al., 2009). Furthermore, since referential learning is assumed to be an automatic process, the account is in line with demonstrations of EC in the absence of contingency awareness (e.g., Dickinson & Brown, 2007; Fulcher & Hammerl, 2001b; Walther & Nagengast, 2006).

1.4.3. The concept categorization account

Davey (1994a) suggested that EC is not based on the formation of associations between memory representations but on conceptual learning (compare also Field & Davey, 1999). Features that a CS has in common with the US are supposed to become more salient during the presentations of the CS-US pairings. This is assumed to increase the probability to categorize the CS as a stimulus of the same valence as the US. Basically, EC effects are accounted by a priming mechanism wherein the US serves as a prime directing attention to congruent features of the CS. The magnitude of EC should depend mainly on the number of co-occurrences and the number of features shared by the CS and the US (Davey, 1994a). Since the salience of CS features can change only when both the CS and the US are presented, neither single presentations of the CS (extinction) nor variations in statistical contingency should affect the valence of the CS. Further, EC effects are expected to be larger when the CS is highly similar to the US. EC should thus be impaired if CS and US belong to different stimulus modalities.

1.4.4. The implicit misattribution account

The recently proposed implicit misattribution account refers to EC as a source-confusion error by which the valence of the US is falsely attributed to features of the CS (Jones, Fazio, & Olson, 2009; Jones, Olson, & Fazio, 2010). That is, contiguous CS-US presentations make the participant believe that the liking or disliking is caused by the CS rather than by the US. These misattributions of valence are supposed to be driven by automatic attitude activations (Fazio, Sanbonmatsu, Powell, & Kardes, 1986), and they should occur implicitly. Any variable that makes it more likely to misattribute the valence of the US to the CS should thus increase the EC effect. Since source confusion errors should be more likely if CS and US are similar, EC is expected to be stronger if CS and US match in modality and if their valences are similar. Further, awareness is expected to counteract with misattributions. EC should thus be more likely when the participants are unaware of the CS-US contingencies. Indeed, Jones et al. (2009) found EC to increase with a number of these variable like the salience of the CS or the spatial proximity between the CS and the US.

1.4.5. The propositional account

The propositional account of associative learning (e.g., De Houwer, 2007, 2009; Mitchell et al., 2009) refers to conditioning effects - whether Pavlovian or evaluative - as the result of the formation and evaluation of propositions about events rather than on the formation of simple associative links between representations. Whereas associative links simply refer to the strength of the relation between two representations, propositional links hold a quality of the relation between the representations. Such a quality can be the causal relation between two events A and B (e.g., the statement 'A causes B') and it can differ in the degree to which it is assumed to be correct. Conditioning is expected to occur to the extent that particular propositions about the CS and the US are considered by the subject to be true. The formation of propositions is assumed to rely on non-automatic processes requiring direct (conscious) experience of the CS-US pairings. Therefore, prior knowledge, instructions or deductive reasoning, for instances, are expected to modulate the conditioning effect.

A crucial difference between propositional and associative models lies in the assumed role of consciousness - and particularly contingency awareness - in learning. The propositional account predicts contingency awareness to be a crucial factor in the acquisition of EC, because it is thought to be necessary for the truth-evaluation of the propositional link which, in turn, is assumed to be necessary for conditioning to occur. Thus, it is rather difficult for this account to explain the occurrence of EC in the absence of contingency awareness (e.g., Dickinson & Brown, 2007; Fulcher & Hammerl, 2001b).

1.5. Research questions

1.5.1. Theoretical framework

The accounts of EC can be categorized with respect to whether they focus on (a) the automatic formation of associations in memory between representations of the CS and the US (i.e. the holistic, the referential, and the implicit misattribution account) or on (b) the impact of higher-order processes such as conceptual categorization or the formation of propositions (see Hofmann et al., 2010). Probably the most prominent outcome of higher-order propositional processes in associative learning is contingency awareness.

With regard to the assumed causal relationship between contingency awareness and conditioning, Lovibond and Shanks (2002) proposed to distinguish between three classes of models. *'Strict' single-process models* assume a single propositional learning process: Exposure to a CS-US contingency in the environment is assumed to enhance contingency awareness (through propositional learning) which in turn is thought to initiate the conditioned response (see Figure 1.1 A1). According to the propositional account, for instance, EC is supposed to result from conscious propositional knowledge about the CS-US relationship which might serve as a justification for (dis)liking an ambiguously valenced CS (De Houwer et al., 2005). *'Weak' single-process models* (Figure 1.1 A2) assume that both contingency awareness and the conditioned response are elicited by the same (propositional) learning process. In contrast to the 'strict' version, however, these models do not assume a causal relation between contingency awareness and conditioning. Thus, they can also explain conditioned responses to be acquired independently of contingency awareness (Baeyens, Eelen, & Van den Bergh, 1990). By contrast, *dual-process models* (Figure 1.1 B) presume two independent learning systems, one that initiates the conditioned response by automatically forming associations between stimulus representations (e.g., the referential learning system; Baeyens et al., 1992), and another one that is responsible for the acquisition of propositional knowledge and awareness (the expectancy learning system). Dual-process models thus do not assume a causal role of contingency awareness in the production of a conditioned response.

Contingency awareness can thus be seen as an outcome of particular propositional-learning processes which might operate, for instance, during the exposure to the CS-US pairings. In order to study the role of propositional learning in EC, it is necessary to define and investigate those cognitive resources that are required during conditioning to enable propositional learning. The studies reported in this dissertation focus particularly on those propositional-learning processes that concern the CS-US contingency information, because these factors are expected to be crucial for the formation of contingency awareness.

Since contingency awareness is typically operationalized by means of a delayed contingency recognition tests (compare section 1.2), it certainly requires the CS-US contingency information to be stored in memory. Thus, successful propositional learning about the CS-US contingency is supposed to be a function of those cognitive factors that have an impact on memory performance. It should be crucial (a) to pay

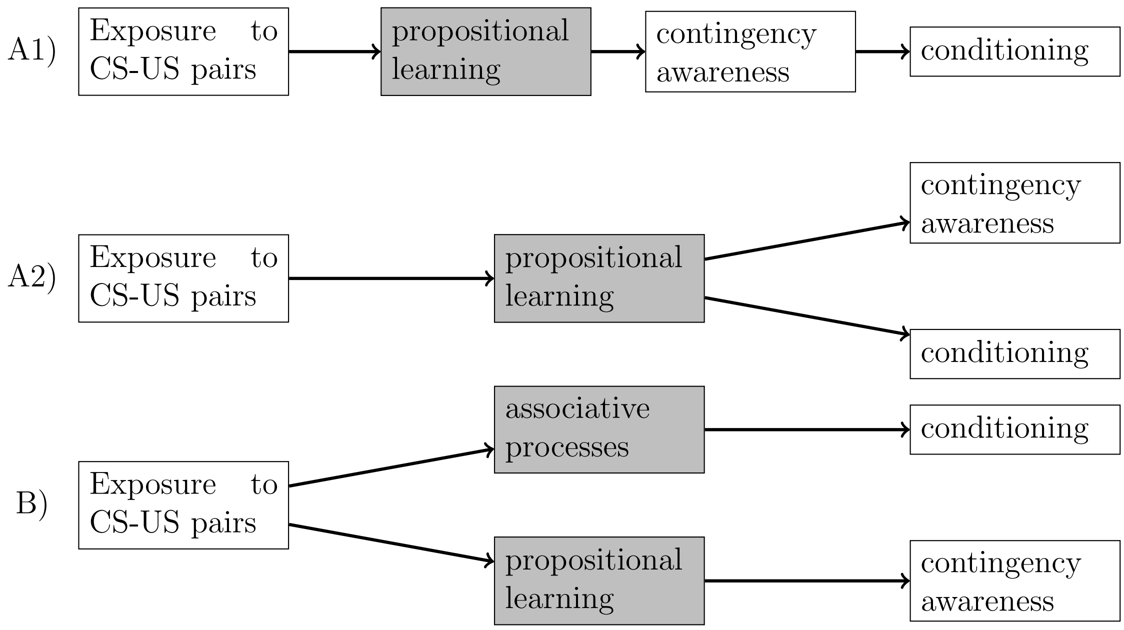

Figure 1.1.: Schematic illustration of 'strict' and 'weak' forms of single-process models (A1 and A2), and dual-process models (B), according to Lovibond & Shanks (2002).

attention to the CS-US contingency information and (b) to retain this information in working memory during the acquisition of EC.

Once, the participant has acquired knowledge about the CS-US pairings (contingency memory), higher-order thinking and reasoning may further modulate the content of the propositional knowledge and help to form sophisticated knowledge about the CS-US relationship. For instance, a participant may acquire knowledge about the statistical contingency between the CS and the US.

The assumed relations between each propositional-learning process (i.e. attention, working memory, long-term memory, and propositional knowledge) and the acquisition of (a) measures of contingency knowledge and (b) EC are illustrated schematically in Figure 1.2. The next section sketches out which aspect of the problem each of the manuscripts addresses.

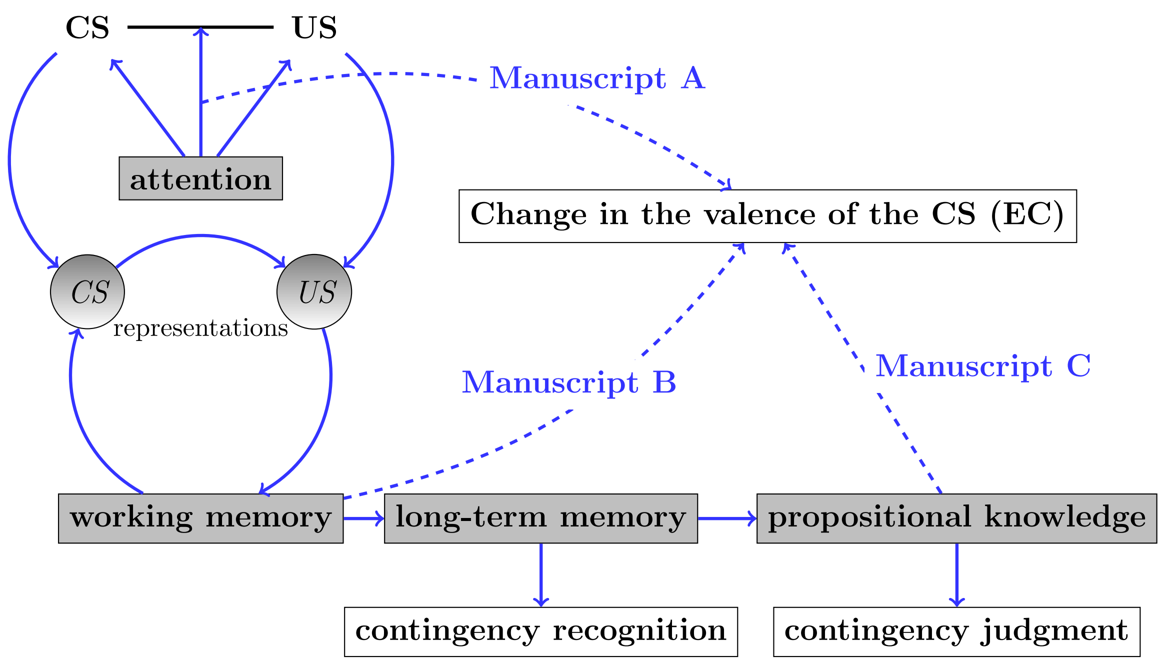

Figure 1.2.: The relations between the three manuscripts and a schematic illustration of the assumed steps (cognitive factors) in propositional learning (gray boxes). Each manuscript addresses the effect of one well-defined process on EC, and its relation with the acquisition of CS-US contingency knowledge. Further explanations are made in the text.

1.5.2. Relations between the manuscripts

The doctoral dissertation focuses on the relationship between EC and those processes that are supposed to be crucial in propositional learning about the CS-US contingencies. New experimental paradigms have been developed in order to manipulate and measure these cognitive factors during the acquisition of EC. The thesis comprises three original manuscripts each reporting one or several experiments on the effect of a particular propositional-learning process (independent variable) on the acquisition of both EC and contingency awareness (see Table 1.1).

Each factor is expected to affect propositional learning during the exposure to CS-US pairings in a particular manner (compare Figure 1.5.1). In a first step, propositional learning is assumed to require attention being focused on the stimuli (i.e. the CS and the US). However, in order to acquire contingency knowledge, it might be crucial to particularly focus attention on the contingency between the CS and the US, as well (see Figure 1.2). Second, representations of these CS-US associations may be built and stored in working memory, and eventually result in long-term contingency memory. Contingency awareness typically refers to this kind of long-term memory since it is quantified as the performance in a post-conditioning recognition test (e.g., Walther & Nagengast, 2006, see Figure 1.2). Finally, after having acquired knowledge about the CS-US contingency, a participant may gain more elaborated propositional knowledge about the strength of the statistical contingency (i.e. whether the CS reliably predicts the occurrence of the US). This type of propositional knowledge is measured typically by means of contingency judgments (see Figure 1.2).

Thus, propositional learning about the CS-US contingencies is assumed to involve three important cognitive factors: (a) the focus of attention, (b) working memory capacity, and (c) propositional knowledge about CS-US contingencies. The acquisition of contingency awareness is expected to require both a focus of attention on the CS-US contingency as well as working memory resources to be available during conditioning. Thus, according to single-process models, these two factors should also determine the occurrence and/or the magnitude of the EC effect. By contrast, dual-process models would expect EC to occur even without attention or working memory resources to be available during the acquisition. The impact of these cognitive resources on the occurrence of EC was investigated in manuscripts A and B. In an experiment reported in manuscript A, the selective focus of attention was manipulated between groups by means of specifically demanding secondary tasks during conditioning. The effect of working memory capacity during conditioning was investigated in a series of experiments reported in manuscript B. Therefore, working memory capacity was limited experimentally by inducing different degrees of phonological-loop disruption during EC with verbal CSs and USs.

After having memorized the CS-US pairings, a participant may acquire elaborated propositional knowledge about the co-occurrences of the CS and the US. The propositional account of EC (e.g., De Houwer, 2009) might expect these propositions to determine the magnitude of the EC effects. Other accounts, however, would rather expect objective variables like the CS-US contingency to have an impact on the occurrence of conditioned responses. The influence of both objective CS-US contingency and elaborated propositional knowledge about the CS-US contingency on EC is addressed in manuscript C. In this manuscript, an experiment is reported that investigated the impact of experimentally modulated contingency judgments on the effect size of EC in participants who are clearly aware of the contingencies.

Taken together, the studies reported in this dissertation focus on the following main research questions:

- Does EC depend on the acquisition of explicit knowledge about the CS-US pairings (manuscripts A, B, and C)?
- Does the occurrence of EC rely on particular focus of attention on the contingencies (manuscript A) and working memory resources to be available during the acquisition (manuscript B)?
- Is the magnitude of EC a function of (a) objective CS-US contingency or (b) propositional knowledge about the strength of the CS-US contingency, or both (manuscript C)?

A summary of the each manuscript is given in the following chapter.

Table 1.1.: Original Manuscripts.

Manuscript	**Reference of the original article**	**Independent variable**	*N*
A (p. 71)	Kattner, F. (in press). Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus. *Cognition and Emotion*.	Focus of attention (between-subjects)	109
B (p. 88)	Kattner, F., & Ellermeier, W. (2011). *Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning*. Manuscript submitted for publication.	Working-memory resources (within-subjects)	109
C (p. 117)	Kattner, F., & Ellermeier, W. (in press). Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning. *Experimental Psychology*	Propositional knowledge / contingency judgments (within-subjects)	31

2. Outline of the thesis

2.1. Manuscript A - “Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus”

2.1.1. Purpose of the study

The results of previous studies suggest, that attentional resources play a crucial role in the acquisition of EC (Field & Moore, 2005; Pleyers et al., 2009). Based on their results, Field and Moore (2005), argue that attention rather than contingency awareness is critical for the acquisition of EC. In their study, contingency awareness was manipulated by means of subliminal presentations of the USs (17 ms exposure and backward masking) whereas attention was manipulated by having the subjects engage in a distraction task (counting backwards). In principle, during the exposure to CS-US pairings, attention can either be focused on (or diverted from) either the stimuli themselves or the contingency between the stimuli. Field and Moore (2005), however, did not distinguish between attention being paid to stimuli (the CS and the US) and attention being paid to the CS-US contingency. Though attention can be focused on the contingency only if it has been assigned to the respective stimuli, it should be possible to assign attention to the stimuli while not monitoring their contingency. A contingency focus of attention, however, is assumed to be crucial in order to acquire contingency awareness. The role of attending to CS-US contingencies during conditioning was investigated in the experiment reported in manuscript A. Particularly, the manuscript is concerned with the question of whether (a) attention in terms of a stimulus focus is sufficient for EC to occur or whether (b) EC requires focusing on the contingencies.

2.1.2. Method

Therefore, a method was developed to specifically prevent subjects from paying attention to the contingencies while still paying attention to the stimuli (contingency-distraction group). Participants in two additional experimental groups were either engaged in a general distraction task (full-distraction group) that is expected to divert attention from the stimuli (solving arithmetic problems, cf. Field & Moore, 2005; Pleyers et al., 2009; Walther, 2002), or in a contingency-focus inducing task (attention-enhanced group) requiring them to memorize the CS-US contingencies (Field & Moore, 2005; Fulcher & Hammerl, 2001b). In order to learn the contingencies, these participants are assumed to have attended both to the stimuli and to their contingencies during conditioning[1]. In line with previous findings, subjects in the attention-enhanced group are expected to show EC after having acquired knowledge about the CS-US contingencies (e.g., Dawson et al., 2007; Pleyers et al., 2007; Stahl & Unkelbach, 2009). However, if attention to the stimuli is sufficient for EC to occur (Field & Moore, 2005), then conditioning effects would be expected to occur in the contingency distraction group as well, because these participants focused their attention to the CS and the US. By contrast, if contingency awareness is crucial for the acquisition of EC (Pleyers et al., 2009), then conditioning should depend on attention being paid to the contingencies. Thus, EC should be diminished in the contingency-distraction group. In any case, EC is not expected to occur in the full-distraction group due to the lack of attention being paid to the stimuli (Field & Moore, 2005).

A total of 109 students were assigned randomly to one of the three experimental groups. They participated in an EC experiment using individually pre-rated visual stimuli (advertisement pictures) as CSs and USs. Pre-post differences of the evaluative ratings of CSs and post-conditioning contingency recognition (contingency awareness) were measured for each CS-US pairing.

[1]In order to show a dissociation between attention and contingency awareness (compare Field & Moore, 2005), it would also be nice to implement an additional condition (i.e. a task) that induces contingency awareness while diverting attention from the stimuli. However, it might be disputed whether it is theoretically and/or empirically possible to acquire contingency awareness without paying attention to the stimuli.

2.1.3. Results and Discussion

As expected, a significant effect of EC was found only in subjects who focused their attention to the CS-US contingencies in order to memorize them (attention-enhanced group) but not if attention was diverted by means of a secondary task. Interestingly, not only the general distraction task but also the specific contingency-distraction task urging the participants to attend to the stimuli eliminated the EC effect. This shows that attention being paid to the stimuli is not sufficient for EC to occur. Rather, a contingency focus seems to be crucial during conditioning. Not surprisingly, participants in the attention-enhanced group memorized the CS-US contingencies better than participants in the two distraction groups did, indicating a greater degree of contingency awareness.

The results of manuscript A are in conflict with two assumptions that have been raised in the literature: (a) that attention (being paid to the stimuli) rather than contingency awareness is critical for EC to occur (Field & Moore, 2005) and (b) that there is a dissociation between EC and contingency awareness (e.g., Fulcher & Hammerl, 2001b). Assuming that a contingency focus is critical for the acquisition of contingency awareness, the observed inhibition of EC with contingency distraction strongly suggest that contingency awareness plays a crucial role in the acquisition of EC (Pleyers et al., 2009). This conclusion is further supported by the results of a mediation analysis implying that the differential effect of the secondary-task manipulation on EC is driven by the level of contingency awareness. To sum up, the results imply that contingency awareness at the time of the acquisition (i.e. a contingency focus) rather than attention in terms of a stimulus focus is crucial for EC to occur.

2.2. Manuscript B - "Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning"

2.2.1. Purpose of the study

Propositional accounts assume that EC relies on the formation and evaluation of propositional knowledge about the CS-US relationship (e.g., De Houwer, 2009). Since contingency awareness is typically measured by means of a delayed recognition test after conditioning, any factor that influences the encoding of CS-US pairs in long-term memory is expected to also have an effect on the acquisition of contingency awareness. The probability to store the CS-US contingency information in long-term memory will be greater, for instance, the more it has been rehearsed in working memory during conditioning (Baddeley, 1986). In line with this, occupying the subject’s working memory, e.g., by means of a tracking task, has been shown to reduce EC (Brunstorm & Higgs, 2002, but see Johnsrude, Owen, Zhao, & White, 1999). Working memory capacity during conditioning is thus supposed to be an important resource of propositional learning and it should have an impact on the acquisition of contingency awareness and - according to the propositional account - on EC. More precisely, the formation of contingency memory is assumed to require stimuli being actively retained in working memory. Representations of the CS and the US (and their contingency) are expected to occupy working memory during the acquisition of EC (e.g., the phonological loop in case of phonological or verbal stimuli, compare Baddeley, 1996, 2003). Consequently, if the acquisition of propositional contingency knowledge is crucial, then EC should be less likely if working memory capacity is constrained during conditioning. In manuscript B, three experiments are reported that assessed the impact of working memory by producing phonological disruption during the acquisition. Therefore, a method was developed to occupy the phonological loop with irrelevant sound differing with respect to how speech-like it is, in a EC procedure with verbal CSs and USs.

2.2.2. Method

A total of 109 subjects participated in one of three EC experiments. Individually pre-rated neutral non-words were used as CSs in all experiments. Standardized affective German nouns (from the Berlin Affective Word List; Vo, Jacobs, & Conrad, 2006) were used as USs in experiment 1. Individually pre-rated liked and disliked non-words were used as USs in experiments 2 and 3. Pre-post differences of the evaluative CS-ratings and contingency memory were measured for each CS-US pairing.

Pairs of words and/or non-words had to be encoded under different conditions of phonological distraction which are expected to produce well-defined degrees of memory impairment. During conditioning, participants were either articulating irrelevant numbers or they were listening to irrelevant speech (a segment of a Korean poem recited by a native speaker adopted by Zimmer, Ghani, & Ellermeier, 2008), or to less-distracting non-speech sound (e.g., frequency-modulated tones). Control pairings were presented either in silence or while white noise was played back (both are expected not to disrupt working memory; see Ellermeier & Zimmer, 1997). Thereby, it was possible to produce graded levels of contingency awareness rather than merely reducing it in an unspecific way as with typical attentional-distraction tasks (e.g., Field & Moore, 2005; Fulcher & Hammerl, 2001b).

2.2.3. Results and Discussion

The results show that the playback of irrelevant speech during verbal EC impaired both the memorizing of the CS-US parings and the conditioning effect. Subjects' CS ratings changed as a function of US valence only if mildly disrupting non-speech sound was played back but not if irrelevant speech (whether it was produced by participants or merely passively processed) impaired the encoding of the CS-US associates. This finding strongly indicates that EC occurs only if the CS-US pairings have been successfully encoded in working memory and it challenges those theoretical accounts which assume EC to rely on automatic association formation processes (e.g., Baeyens et al., 1992; Martin & Levey, 1994; Walther & Langer, 2008). However, EC occurred independently of whether the participants were able to recognize the respective CS-US contingencies in a delayed test of contingency awareness. This indicated that EC does not necessarily depend on the acquisition of long-term knowledge about the contingencies. Rather, it seems to be crucial that the CS-US pairings have been consciously processed (rehearsed) in working memory during the acquisition phase.

2.3. Manuscript C - "Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning"

2.3.1. Purpose of the study

After having rehearsed the CS-US pairings sufficiently, the participant is assumed to store the contingencies in long-term memory. There is a great number of studies (although they are reporting controversial results) in which the subsequent recall of contingency knowledge has been utilized as a measure of contingency awareness (e.g., Baeyens, Eelen, & Van den Bergh, 1990; Hammerl & Fulcher, 2005; Pleyers et al., 2009; Stahl et al., 2009; Walther & Nagengast, 2006). Contingency knowledge thus basically refers to the participant's ability to identify CS-US pairings (i.e. contiguity), but not to knowledge about the strength of the contingency. According to propositional accounts of EC, however, it might be possible that more sophisticated knowledge about the CS-US relationship has an impact on EC. Interestingly, the role of knowledge about the CS-US contingency (i.e. contingency judgments) has been neglected so far both in empirical studies and in theoretical accounts of EC. Even propositional models which assume that evaluative learning relies on the formation of propositional knowledge concerning the CS-US relationship (e.g., De Houwer, 2007, 2009), did not make any clear predictions on whether propositions about the strength of the CS-US contingency should affect EC. It has been considered possible, however, that propositions about the statistical contingency mediate EC (e.g., Hofmann et al., 2010, p. 394). Higher contingency judgments may strengthen the belief that the CS and the US are related and consequently lead to stronger conditioned responses. However, there are no studies, yet, that experimentally manipulated the participants' conscious beliefs about the CS-US relations during EC (Hofmann et al., 2010). This was the aim of the present experiment. A method was developed that allows to independently study the impact of objective contingency and subjective contingency judgments on the magnitude of EC. In line with Baeyens et al. (1993), objective contingency is not expected to affect EC. However, propositions about a strong CS-US contingency are expected to produce stronger EC effects than propositions about a weak CS-US contingency. Further, in order to extend the scope of EC, it was intended to demonstrate EC within a new sensory modality of the CSs (i.e. auditory stimuli).

2.3.2. Method

In manuscript C, an experiment is reported in which participants' contingency judgments were modulated independently from the objective CS-US contingency by making use of the outcome density bias. This bias refers to the phenomenon that the statistical contingency between a cue and an outcome that occur with constant contingency is judged to be stronger if the outcome occurs frequently (e.g., Allan & Jenkins, 1983). By combining the EC procedure with a contingency-learning paradigm, both the CS-US contingency (in terms of ΔP, equation 2.1, cf. Allan, 1980) and US density ($P(US)$) were varied during the acquisition of EC in order to modulate the subjective contingency judgments between different CS-US pairings.

$$\Delta P = P(US|CS) - P(US|\neg CS) \tag{2.1}$$

A total of 31 subjects participated in an EC experiment with auditory CSs (environmental sounds) and visual USs (IAPS pictures; Lang, Bradley, & Cuthbert, 2008). CS-US pairings were presented in two separate learning blocks. Objective contingency varied between blocks and US density varied within blocks. After each block, evaluative responses, contingency memory and contingency judgments were measured for each CS-US pairing.

2.3.3. Results and Discussion

Contingency judgments were higher in the high-contingency block ($\Delta P = .75$) than in the low-contingency block ($\Delta P = .5$) and they decreased with an increase of US density from $P(US) = .1$ to $P(US) = .3$. This shows that the participants were able to notice the objective contingencies (ΔP), but their contingency judgments were (successfully) biased by US density. The observed effect of outcome density on contingency judgments is similar to previous results (e.g., Wasserman, Elek, Chatlosh, & Baker, 1993). Since contingency judgments were not affected by contingency but only by an interaction between contingency and US density, the outcome density effect appears to have modulated the subjective beliefs about the contingencies independently of the objective values of contingency. The study also revealed an overall EC effect. Comparable effect sizes of EC were observed with high and low values of contingency, indicating that EC is not sensitive to the CS-US contingency. The magnitude of the conditioning effect, however, was affected by an interaction of contingency and US density, and it was positively correlated with the contingency judgments. Bigger EC effects were observed in those contingency × US density conditions that produced higher contingency judgments.

The results provide evidence for contingency judgments to have an impact on the acquisition of EC. The appraisal of a strong CS-US contingency appears to produce larger EC effects. Thus, while knowledge about the CS-US contiguities (contingency awareness) is assumed to be necessary for the acquisition of EC, propositional knowledge about the contingencies may modulate the size of the EC effect. This strongly challenges the assumption that EC relies (only) on automatic processes (e.g., Baeyens et al., 1992). However, the effect can be explained with the propositional account of EC (e.g., De Houwer, 2009). The results are in line with the idea that EC is sensitive to propositions about the CS-US contingency: Strengthening the subjective belief that CS and US are statistically related enhances EC.

3. General discussion and conclusions

3.1. Summary of results

The present doctoral thesis consists of three manuscripts that are in press or under review with refereed journals. They report five experiments studying a total of 249 participants showing that evaluative learning is sensitive to a specific focus of attention, the availability of working-memory resources, and subjective beliefs about the CS-US contingencies. Each of these factors were shown to modulate the effect size of EC, that is the standardized repeated-measures difference of the means of the evaluative rating shifts of CSs that were paired with positive and negative USs (CS_{pos} and CS_{neg}, respectively; see equation 3.1 and Cohen, 1988). A summary of the observed effects sizes of EC and the levels of contingency awareness reached in each experimental condition are shown in Table 3.1.

$$d = \frac{M_{CS_{pos}} - M_{CS_{neg}}}{\sqrt{\frac{{SD_{CS_{pos}}}^2 + {SD_{CS_{neg}}}^2}{2}}} \tag{3.1}$$

Manuscript A started by investigating what attention must be focused on before EC effects occur. The crucial finding of this experiment was that - although attention may be focused on the CS and the US - there is no EC when participants are not attending to the CS-US contingency. A medium effect size (Cohen, 1988) of EC was found only when subjects focused on the contingencies and acquired contingency awareness (Table 3.1). This implies that attention to the stimuli is not sufficient for EC to occur. Rather, EC seems to require a more specific focus on the contingencies between stimuli which is supposed to be crucial also for the acquisition of contingency awareness.

Manuscript B sheds light on the role of working memory capacity during EC. Particularly, the encoding of CS-US pairings (and thus the acquisition of contingency knowledge) was disrupted by simultaneously presenting irrelevant materials which are supposed to gain automatic access to the same working memory module (i.e. the phonological loop). These irrelevant materials consistently (a) produced a gradual decrement in contingency awareness (approximately 10-20%, compare Table 3.1) and (b) interfered with the acquisition of EC. Medium effect sizes of EC were found only if the CS-US pairs were presented either in silence or together with (mildly disrupting) non-speech sounds (except for experiment 1 where a considerable level of contingency awareness and EC was observed in the irrelevant-speech condition, as well; see Table 3.1). These result indicate that evaluative learning requires a certain amount of working-memory resources to be available during conditioning. If working memory is occupied by different (irrelevant) materials, then EC is less likely to occur, presumably because the subject is not able to encode the CS-US pairings. However, additional item-based analyses (compare Pleyers et al., 2007) revealed that conditioning was not restricted to those pairings that the participants recognized in a subsequent test. Though working-memory resources are crucial during conditioning in order to encode the CS-US contingencies, evaluative learning may thus not necessarily depend on the acquisition of long-term contingency knowledge.

Manuscript C looked at the appraisal of the contingency relationship between the CS and the US in greater detail. Here, the perceived CS-US contingency was manipulated successfully during evaluative learning by taking advantage of a judgment bias that is caused by US density modulations (e.g., Allan & Jenkins, 1983). Participants were either biased to believe that the CS strongly predicted the US or not, independently of how strongly the CS objectively predicted the US (in terms of ΔP, Allan, 1980). Similar to the results shown by Wasserman et al. (1993), an increase of US density from 10 to 30% came along with a decrease in the contingency judgments irrespective of whether the objective contingency was high ($\Delta P = .75$) or low ($\Delta P = .5$). Considerable effects of EC were found in all experimental conditions, probably due to the fact that participants were aware of most of the contingencies (compare Table 3.1). The effect size of EC, however, was affected by an interaction of contingency and US density, but not by objective contingency alone. Furthermore, the magnitude of EC was positively correlated with the subjective appraisal of the CS-US contingency. This result implies that evaluative learning is sensitive to modulations of the propositional knowledge about the relation between the CS and the US. Once a participant has successfully memorized the CS-US contiguities (which should be crucial for the acquisition of EC, compare manuscripts A and B), the subjective appraisal of the strength of the CS-US contingencies appears to determine the magnitude of the EC effect.

Table 3.1.: Summary of the effect sizes of EC in the studies reported in manuscripts A, B, and C.

Study	**Condition**	**Propositional-learning process**	N	**Contingency awareness**	**Effect size (EC)**	p
A	Attention enhanced	attention (+), contingency focus (+)	38	99%	$d = 0.54$	$***$
A	Contingency-distraction	attention (+), contingency focus (-)	32	62%	$d = 0.06$	.80
A	Full distraction	attention (-), contingency focus (-)	39	52%	$d = 0.02$	.93
B, exp. 1	Silence	working memory (+)	29	80%	$d = 0.47$	$*$
B, exp. 1	Irrelevant speech	working memory (-)	29	83%	$d = 0.47$	$*$
B, exp. 1	Articulatory suppression	working memory (-)	29	73%	$d = 0.28$	.33
B, exp. 2	Silence	working memory (+)	40	57%	$d = 0.40$	$*$
B, exp. 2	Irrelevant speech	working memory (-)	40	51%	$d = 0.25$	.11
B, exp. 2	Articulatory suppression	working memory (-)	40	45%	$d = 0.08$	.34
B, exp. 3	Noise	working memory (+)	40	70%	$d = 0.61$	$**$
B, exp. 3	FM tones	working memory (+)	40	65%	$d = 0.75$	$***$
B, exp. 3	Irrelevant speech	working memory (-)	40	51%	$d = 0.12$	.29
C	$\Delta P = .5, P(US) = .1$	contingency judgment (53.7)	31	99%	$d = 0.80$	$**$
C	$\Delta P = .5, P(US) = .3$	contingency judgment (46.7)	31	99%	$d = 0.33$	.14
C	$\Delta P = .75, P(US) = .1$	contingency judgment (65.2)	31	90%	$d = 0.41$	.16
C	$\Delta P = .75, P(US) = .3$	contingency judgment (57.0)	31	88%	$d = 0.83$	$**$

$***p < .001$; $**p \leq .01$; $*p < .05$

3.2. Theoretical significance

The results reported in manuscript A are in line with 'strict' single-process models (e.g., the propositional account; De Houwer, 2007, 2009) assuming contingency awareness to be necessary for the acquisition of EC: Conditioning was shown to occur only if the participants specifically focus their attention on the CS-US contingencies during the acquisition. By contrast, the holistic and the referential account of EC (Martin & Levey, 1978; Baeyens et al., 1992) as well as other automatic association-formation models (e.g., Walther & Langer, 2008) do not predict EC to rely on attention being particularly paid to the contingency. Since these models assume EC to be driven by automatic processes, there should be no effect of attentional distraction at all. Thus, it is hard to explain the results reported in manuscript A with these models. It is also difficult to explain the observed EC effects by assuming an implicit misattribution of the US valence to features of the CS being (Jones et al., 2009), because such misattributions are supposed to be less likely when attention is focused on the relevant stimuli. By contrast, implicit misattributions should be more likely to occur with diverted attention.

The experiments reported in manuscript B basically show that EC is sensitive to working-memory capacity. The acquisition of both contingency awareness and EC was shown to depend on the availability of working-memory capacity. This is in line with 'weak' and 'strict' forms of single-process models (compare Lovibond & Shanks, 2002) assuming that the exposure to CS-US pairings leads to both contingency awareness and the acquisition of an evaluative response. Fulcher and Hammerl (2001a) argue that if there is a causal relation between contingency awareness and EC ('strict' single-process models), then the conditioning effect should increase when awareness is enhanced and it should decrease when awareness is reduced. Since distinct levels of contingency awareness were induced experimentally by producing well-defined working memory disruptions, the results of these experiments are in favor of the 'strict' hypothesis that there is a causal effect of contingency awareness on EC. However, this conclusion refers contingency awareness to the amount of CS-US contingency information that is kept in working memory during the acquisition of EC. Long-term contingency memory (as measured in many previous studies; e.g., Baeyens, Eelen, & Van den Bergh, 1990; Fulcher & Hammerl, 2001b; Walther & Nagengast, 2006) might be less relevant. So far, the impact of working-memory resources on EC has been shown only with verbal stimuli. In order to extend the scope of this effect, future studies may want to utilize procedures with the CS and the US being presented in different modalities thus calling for different working memory modules.

Manuscript C provides further evidence that elaborated propositional knowledge about the CS-US relation can influence the magnitude of the EC effect. Comparable effect sizes of EC were found with low and with high levels of objective contingency (compare Table 3.1). This is consistent with the finding that the CS does not have to be a predictive cue for the occurrence of the US in EC (Baeyens et al., 1993). Independently of objective contingency, however, the subjective appraisal of a strong CS-US contingency was shown to go along with greater EC effects. It is difficult to explain the results of this study by Pavlovian conditioning theories assuming that learning should be a function of contingency (e.g., Rescorla, 1968, 1988). The insensitivity to contingency is more in line with the referential account explaining EC as a simple form of Hebbian learning in which the CS only activates the US without generating an expectancy of the US to occur immediately (Baeyens et al., 1992, 2001). According to these and similar accounts (Martin & Levey, 1978; Walther & Langer, 2008), EC should be primarily determined by the number of CS-US pairings. This assumption, in turn, is challenged by the finding that EC was modulated by an interplay of contingency and US density. The participants' subjective appraisal of the CS-US contingencies was affected by an interaction of contingency and US density, as well. Furthermore, since EC was correlated with these subjective contingency judgments, the pattern of results reported in manuscript C is accounted best by assuming that propositions about the predictive relationship between the CS and the US foster the evaluation acquired. Thus, the finding is particularly relevant for the propositional account assuming EC to result from cognitively evaluated propositions about the relation between the CS and the US (De Houwer, 2007). The appraisal of a strong CS-US contingency could have fostered the propositional link between the CS and the US, and the participants might have used this propositional knowledge to infer how much they liked the CS (De Houwer et al., 2005).

To sum up, the results imply that EC - like other forms of Pavlovian conditioning (e.g., Lovibond & Shanks, 2002; Mitchell et al., 2009) - is not driven by simple automatic Hebbian learning processes. Rather it seems to be a function of - at least - attentional, mnemonic and higher-order propositional-learning processes. The results reported in manuscripts A and B both show that EC depends on those cognitive resources that enable propositional learning and the acquisition of contingency knowledge (i.e. a contingency focus of attention and working-memory resources). In manuscript C, it is further shown that EC is sensitive to subjective beliefs about the CS-US contingency. Thus, particularly the results reported in manuscript C are best accounted for by assuming that the acquisition of EC involves the formation of propositional knowledge about the CS-US relation (cf. De Houwer, 2007, 2009).

Nevertheless, although EC, like other forms of Pavlovian conditioning appears to require a certain amount of conscious awareness and attention, there seem to be functional differences, as well. Replicating previous findings, (e.g., Baeyens et al., 1993), it was shown in manuscript C that EC occurs independently of objective values of contingency. Similarly other recent the studies have shown that EC, unlike other forms of conditioning, is not sensitive to extinction (e.g., Dwyer et al., 2007) and blocking (Beckers et al., 2009). This implies that EC is subject primarily to higher-order cognitive variables (i.e. subjective appraisal) rather than to those procedural variables that are known to modulate the extent of conditioned responses in other forms of associative learning.

3.3. Practical implications

Notwithstanding the fundamental research perspective of the present thesis, it is possible to derive a few tentative conclusions with respect to applications of the EC phenomenon.

Particularly with respect to advertising psychology, practical implications may be derived from the results shown in manuscript A. Whenever a commercial intends to yield a positive appraisal of a product by pairing it with other positively valenced stimuli (e.g., holiday scenes, healthy and sporty people or beautiful women), the advertiser has to assure that the observers of the commercial do not only attend to the stimuli themselves but also to the relation between the product and these positive stimuli. This might be accomplished by presenting the product in close temporal or spatial proximity with the reinforcer or by introducing a salient relation between the product and the positive stimuli with regard to contents. Furthermore, it will be easier for an observer to attend to the CS-US contingency if there are not too many other - maybe more plausible - contingencies present in a commercial. For example, attention might be distracted from the contingency between the happiness of a person and a the consumption of a particular yoghurt if the observer notices another salient contingency between happiness and physical exercises.

The results of manuscript B might also have practical implications for the design of advertisements, particularly television commercials. In order to achieve an affective change with respect to the product, advertisers should take care not to overload a spot with irrelevant content. Whenever plenty of additional stimuli are presented during a commercial in the same stimulus modality (thus calling for the same working memory module) as either the product (CS) or the affective stimulus (US), encoding the contingency might be impaired, preventing the observer from acquiring the desired attitudes towards the product. Nevertheless, future studies should investigate the role of working memory capacity in more realistic consumer settings, and also with visual stimuli, for instance.

In manuscript C, it was shown that EC is sensitive to propositional knowledge about the statistical CS-US contingency. This has practical implications, for instance, with respect to taste preferences and aversions. In order to change the aversion of - say low-fat products - it is not sufficient to only pair them with highly positive stimuli (e.g., healthiness), but to make the person believe that low-fat products are contingently associated with healthiness (i.e. they should be supposed to induce healthiness). In order to make the observer believe in a strong causal relationship between the product and a reinforcing outcome, advertisers may want to take advantage of contingency-judgment biases like the outcome density effect (see Allan, 1993, for a review on biases in contingency learning). A rather simple alternative could be to present the product in close temporal and/or spatial proximity with the outcome which is also known to increase the perceived causal efficacy (e.g., Anderson & Sheu, 1995). The results imply that evaluative responses towards stimuli (e.g., acquired aversions) can be changed even without actually confronting the subject with the stimulus contingencies. Instead, it seems to be crucial to change the subject's beliefs about the co-occurrences with certain (negative) outcomes. This, however, may not hold true for Pavlovian conditioning of physiological or behavioral responses (cf. Vansteenwegen et al., 2006). Future applied studies thus have to show whether propositional knowledge about the CS-US contingency has an effect on variables like purchase intention or purchase behavior, as well.

3.4. Limitations and future perspectives

The present studies have shown that attention, working memory and propositional knowledge influence the acquisition and/or the magnitude of EC. It appears reasonable that a contingency focus of attention is necessary in order to successfully encode the CS-US contingency in working memory which in turn is assumed to be precondition for the acquisition of contingency knowledge (compare Figure 1.5.1). This assumed sequence of processes, however, has not been addressed directly in this work. Future studies should clarify (a) the interrelations between attention and working memory during the acquisition of EC, and (b) the causal relation between these resources on the formation of contingency judgments, contingency awareness and EC. Furthermore, it should be purposed to separate the cognitive resources that are necessary for EC to occur (e.g., a contingency focus) from those processes that modulate the magnitude of EC effects (e.g., contingency judgments).

As outlined above, the fact that propositional processes seem to be involved in the acquisition of new affective-evaluative responses is of great theoretical and practical importance. However, it would be premature to conclude that automatic processes will not contribute to the acquisition of EC. In order to account for the conflicting results with respect to contingency awareness (e.g., Fulcher & Hammerl, 2001b; Dickinson & Brown, 2007; Walther & Nagengast, 2006), future EC studies should try to identify those conditions in which the evaluative learning may be elicited automatically, i.e. without attention or working memory capacity available. In a recent study by Ruys and Stapel (2009, but see Dedonder, Corneille, Yzerbyt, & Kuppens, 2010) one potential factor has been identified that appears determine whether contingency awareness is required or not for EC to occur. Their data indicate that the novelty of the CS may be a moderating variable. Whereas EC was demonstrated in the absence of contingency knowledge for high-novelty stimuli, awareness seems to be necessary to change the liking of an already well-known CS. Thus, automatic processes might be more relevant for the acquisition than for the change of affective-evaluative responses. Furthermore, novelty or familiarity may also have an impact on controlled propositional-learning processes like explicit memory or attention which were shown to be crucial during EC. Automatic processes might, for example, direct attention to the CS-US contingencies during conditioning and thus contribute to the acquisition of EC. More studies are needed that intend to separate automatic and controlled sources of EC (e.g., by means of the method introduced by Jacoby, 1991[1]; see Fulcher & Hammerl, 2001b).

In line with De Houwer's (2007) conceptual analysis, EC has been defined as an effect rather than as a process in the present thesis: It has been referred to the actual change in the valence of stimuli due to the fact that they were paired in a certain manner. This definition implies that there can be different causes of the same EC effect, and some of these causes may in fact be automatic processes, not requiring conscious awareness about the CS-US relationship. The studies reported in this doctoral dissertation, however, strongly suggest that aware propositional learning about the CS-US contingencies does not counteract with EC (compare Hammerl & Fulcher, 2005), but rather produces reliable effects of EC. This mechanism was shown to require a specific focus of attention as well as working memory capacity to be available during the exposure to the CS-US pairings.

[1] To dissociate conscious (intentional) and automatic processes, Jacoby (1991) combined a facilitation paradigm with an interference paradigm. Whereas in the first kind of task, automatic processes are supposed to facilitate performance (e.g. priming in a stem completion task, Forster, Booker, Schacter, & Davis, 1990), in the latter one, automatic processes tend to produce errors (e.g. in the Stroop task; Stroop, 1935). The logic is that the contributions of intentional (I) and automatic (A) processes can be computed by comparing the performance in a facilitation task where automatic and intentional influences act in concert ($performance = A + I$) with the performance in an interference task in which they act in opposition ($performance = A - I$). In the context of a memory recognition test, intentional processes (recollection) are used either to increase the probability of correct recognitions by selecting items (facilitation) or to decrease the probability of false recognitions by rejecting items that stem automatic influences (interference).

4. References

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Part II.

Original Manuscripts

5. Manuscript A

Kattner, F. (in press). Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus. *Cognition and Emotion*. doi: 10.1080/02699931.2011.565036. [1]

Abstract

Although evaluative conditioning has occasionally been demonstrated in the absence of contingency awareness, many recent studies imply that its acquisition depends on the availability of attentional resources during conditioning. In previous experiments attention has typically been manipulated in a general way rather than looking at the particular focus of attention. The present study investigated the role of a focus on the CS-US contingency. Two separate distraction tasks were designed that either diverted attention from the stimuli or directed it to the stimuli while drawing attention away from the contingency between the stimuli. Both types of distraction were shown to eliminate evaluative conditioning. Significant evaluative conditioning was observed in a third group of participants who were required to attend the contingencies. A mediation analysis showed that the observed discrepancy in evaluative conditioning effects between groups was mediated by contingency awareness. The results imply that attention in terms of a stimulus focus is not sufficient for evaluative conditioning to occur. Rather, attention to the contingencies between stimuli appears to be crucial in evaluative conditioning, because it is supposed to foster the acquisition of contingency awareness.

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Keywords: evaluative conditioning; contingency awareness; attention; contingency focus; distraction

5.1. Revisiting the relation between contingency awareness and attention: Evaluative conditioning relies on a contingency focus

Evaluative conditioning (EC) refers to a change in the valence of a stimulus that results from pairing it with an affective stimulus. During the acquisition phase of a typical EC paradigm (Levey & Martin, 1975; Baeyens, Eelen, & Van den Bergh, 1990), stimuli (conditioned stimuli; CS) are presented together with either a strongly liked or disliked stimulus (the unconditioned stimulus; US). This usually produces a change in the liking of the CSs in the direction of the valence of the US which can be measured, for instance, by means of subjective ratings before and after the acquisition phase. Thus, EC is a form of conditioning that looks at changes in the liking of the CS (e.g. De Houwer, 2007). However, the phenomenon is not yet fully understood and there appear to be functional dissociations between EC and other forms of Pavlovian conditioning (e.g. autonomic conditioning) concerning, for instances, the role of statistical contingency between the CS and the US (e.g. Baeyens, Hermans, & Eelen, 1993), or cue competition (e.g. blocking; Beckers, De Viqo, & Baeyens, 2009, but see Purkis & Lipp, in press).

The most controversial question in EC research, however, refers to the importance of cognitive resources available during the acquisition, and particularly the question of whether EC depends on contingency awareness (e.g. Jones, Olson, & Fazio, 2010). Classical conditioning is assumed to occur only after the participant has become aware of the contingencies between the CS and the US (Lovibond & Shanks, 2002; Mitchell, De Houwer, & Lovibond, 2009). Having participants work on a distraction task during autonomic conditioning was shown to reduce both contingency awareness and the strength of conditioned electro-dermal responses (e.g. Dawson, 1970). By contrast, EC has been reported in subjects who were unable to recall the stimulus contingencies (e.g. Baeyens et al., 1990; Walther & Nagengast, 2006) and even after having experimentally reduced contingency awareness either by means of a distraction task (e.g. Fulcher & Hammerl, 2001) or by presenting the USs subliminally (De Houwer, Baeyens, & Eelen, 1994; De Houwer, Baeyens, & Hendrickx, 1997). Some studies even reported a reversal of the typical valence shift when contingency awareness had been induced (Fulcher & Hammerl, 2001; Hammerl & Fulcher, 2005). In opposition to these findings, however, many recent studies reported EC to occur (a) only in subjects who were aware of the CS-US contingencies and (b) only in those pairings that a subject was aware of (e.g. Pleyers, Corneille, Luminet, & Yzerbyt, 2007; Stahl & Unkelbach, 2009; Stahl, Unkelbach, & Corneille, 2009). In fact, although reliable effects of EC have been identified in the absence of contingency awareness, as well, a recent meta-analysis reported the effects to be larger in participants who were aware of the contingencies (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). Stahl et al. (2009) proposed to distinguish between remembering a particular US (identity awareness) and remembering the valence of the US (valence awareness), and their results imply that valence awareness is sufficient for EC to occur.

There are two common strategies to experimentally manipulate the acquisition of contingency awareness: Whereas subliminal presentation techniques are assumed to prevent the (conscious) perception of the US and thus to make it impossible to become aware of the CS-US contingency (De Houwer et al., 1997), distraction tasks are supposed to reduce awareness by diverting the subject's attention (Fulcher & Hammerl, 2001). It is unclear, however, whether an effect of distraction on EC is due to the reduction of contingency awareness or to a lack of attention. To separate the effects of attention and contingency awareness, Field and Moore (2005, experiment 2) conducted a study that directly compared both methods: Contingency awareness was manipulated by varying the US exposure duration and attention was manipulated via secondary tasks. Attention was either enhanced by asking the participants to memorize the order of the stimuli or diverted by means of a counting-backwards task. EC occurred only in participants who focused their attention to the CS and the US, irrespective of whether the USs were presented subliminally or supraliminally. There was no EC in distracted participants. These results imply that the focus of attention rather than contingency awareness is crucial during the acquisition of EC (Field & Moore, 2005)[2]. Similarly, Pleyers, Corneille, Yzerbyt, and Luminet (2009)

[2]Field and Moore (2005) reported that more participants became aware of the supraliminally presented contingencies in the non-distracted group than in the distracted group. Thus the manipulation of attention may also have affected contingency awareness. Statistically, however, contingency awareness as a covariate did not affect EC. Further, if contingency awareness was

found EC to be eliminated if attention is diverted during the acquisition by having participants work on a two-back task. However, they argued that the attentional effects on EC can be explained with differences in contingency awareness.

To account for these rather controversial effects of attentional distraction on EC (compare Field & Moore, 2005; Fulcher & Hammerl, 2001; Pleyers et al., 2009), it might be helpful to have a closer look at the particular focus of attention during conditioning. Previous studies did not look at whether attention had been focused (a) on the stimuli (i.e. the CS and the US) or (b) on the contingency relationship between these stimuli. Whereas a contingency focus is supposed to be possible only if attention has been assigned to the stimuli, participants might attend to the stimuli without focusing on the contingency. Furthermore, a contingency focus might be necessary for the acquisition of contingency awareness. It is unclear whether distraction tasks like those used in previous studies (e.g. Fulcher & Hammerl, 2001) diverted attention from the stimuli or whether they only prevented the participants from attending to the contingencies. This distinction could be crucial with regard to the divergent results, since the acquisition of EC might depend on a specific focus of attention during conditioning. If attention being paid to the stimuli is sufficient for EC to occur (Field & Moore, 2005), then it should not matter whether attention has been assigned to the contingency relationship or not. However, if contingency awareness is crucial during the acquisition (Pleyers et al., 2009), then EC should depend on a contingency focus and be affected also by a task that selectively diverts attention from the contingency but not from the stimuli themselves. Thus, particularly with respect to presumed importance of contingency awareness (Hofmann et al., 2010), it would be interesting to test whether EC depends on a contingency focus.

The present study intends to manipulate the focus of attention during conditioning. For this purpose, two separate distraction tasks were employed, one that generally captured attention like it was done in previous studies (*full distraction*; see Field & Moore, 2005; Fulcher & Hammerl, 2001; Pleyers et al., 2009), and one that interfered with a contingency focus without diverting attention from the stimuli (*contingency distraction*). The contingency focus was discouraged by asking the subjects to learn additional irrelevant contingencies (i.e. associations of each CS and US with a random digit). This task requires the subjects to pay attention

crucial, then no EC would have been expected with subliminally presented USs.

to the stimuli. In a third group, participants were asked to memorize the CS-US pairings (similar to the *attention-enhanced* group by Field & Moore, 2005). In contrast to both distraction groups, participants in this group are supposed to acquire contingency awareness.

If attention is sufficient for EC to occur, then conditioning effects should be found in the contingency distraction group and in the attention-enhanced group. By contrast, if EC depends on a contingency focus (and/or contingency awareness at the time of conditioning) then the contingency-distraction task should interfere with EC and reliable EC effects would be expected to occur only in the attention-enhanced group.

5.2. Method

5.2.1. Participants

A total of 109 students (85 female) with a mean age of 24.1 ($SD = 5.6$) years were recruited at the Technische Universität Darmstadt and randomly assigned to either the *attention-enhanced* group ($n = 38$), the *contingency-distraction* group ($n = 32$) and the *full-distraction* group ($n = 39$). By deliberately not including advanced students of psychology, the probability of subjects being naïve with respect to the conditioning hypothesis was increased. The experiment was run within a course in a computer pool with groups of seven to twenty-four persons tested simultaneously. A session took about 45 minutes. The subjects received course credits for participation.

5.2.2. Stimuli and Apparatus

The stimulus set consisted of 55 pictures of ads showing either people (e.g. eating, smoking or sport activities), natural sceneries (e.g. an office or a vineyard), or objects (e.g. vases or cars). The stimuli did not contain any product information or verbal content. The pictures were digitized as 500 × 666 pixel image files (256 colors) and displayed centered in upright format against a gray background on a widescreen TFT monitor. Stimulus presentations and evaluative response registrations were controlled by a MATLAB script using the Psychphysics Toolbox extensions (Brainard, 1997; Pelli, 1997).

5.2.3. Procedure

Each participant was seated in front of a monitor on which the first instruction was shown containing a cover story on the assumed aim of the study. In order to mask the conditioning procedure, subjects were told that the study investigated the effect of liked and disliked artworks on concentration (in the full-distraction group since their main task was to solve arithmetic problems) or on learning and memory performance (in the other groups since their main task was a learning task). Since the experiment was run within a course, the participants were instructed not to talk during the experiment and they were encouraged to ask questions by calling a tutor prior to each new task when they saw the specific instructions. Neighbors were always assigned to different experimental conditions. The experimental session consisted of three sequential phases: baseline, acquisition and test.

The *baseline phase* was identical for the three groups. The pictures were presented in randomized order and the participants had to evaluate each stimulus by means of a 21-category scale ranging from -10 (disliked) through 0 (neutral) to $+10$ (liked). Responses were given by clicking with the mouse on an area of the scale. They were encouraged to make quick and spontaneous responses. The first 10 ratings were used as training trials to familiarize the participant with the rating procedure and these stimuli were not used in the following phases. Based on the remaining ratings, 3 pairs consisting of a neutral picture (the ratings of which fell closest to zero) and a liked picture (highest ratings) and 3 pairs of a neutral and a disliked picture (lowest ratings) were randomly assigned for each participant.

During the *acquisition phase*, these 6 picture-picture pairings were presented 10 times each in randomized order. The same pairing did not appear in more than two consecutive trials. In each trial, the CS preceded the US. Both stimuli were presented for 2 s and separated by a trace interval of 1 s. The inter-trial interval was 4 s. Subjects in the *attention-enhanced* group had to learn those stimulus pairings. They were informed that their learning success would be tested at the end of the experiment (see appendix for the instruction). In the *full-distraction* group, math equations were presented during the paired stimulus presentations (two-digit summation and subtraction) and the subjects had to decide whether the equation was correct or not by pressing a key (see appendix). To divert attention from the stimuli in the center, the equations were randomly presented at the margins of the screen (top, bottom, left or right). Each equation disappeared as soon as a response was made. In order to guarantee that the equations appeared in all stages of a conditioning trial (i.e. during stimulus exposure and during the intervals in between), they were displayed for a randomly distributed maximum period of time (between 6 and 12 s). The subjects had time to solve a problem until the next problem appeared. A feedback was shown immediately after each response telling the subject whether the response was correct. Participants in the *contingency-distraction* group had to work on an irrelevant pair-associate learning task which was designed to focus their attention to the stimuli while suppressing a focus to the contingencies between the stimuli (see appendix). Their task was to learn 12 randomly generated contingencies between each of the 12 pictures (CSs and USs) and a number (1, 2 or 3). They were required to press the respective key on the numeric pad whenever a picture appeared. After responding, a short text message was presented above the stimulus indicating whether the response was correct (e.g. '1 is correct.'). The feedback was shown until the picture disappeared, and it had to be used to learn the picture-number contingencies.

In the *test phase*, subjects were asked to rate each picture a second time by means of the same procedure as in the baseline phase. Afterwards, participants had to recall the picture-picture pairings that were presented in the acquisition phase in a forced-choice recognition test. Each CS was presented successively on the left side of the screen together with a randomly arranged 3×2-matrix showing the 6 pictures which had presented as USs during the conditioning phase on the right side of the screen (3 liked and 3 disliked pictures). The participants had to choose the picture in the matrix that had previously been paired with the picture on the left by clicking on it. They were requested to guess in case of uncertainty. A participant was classified as identity-aware of a pairing if he or she identified the respective US. If a participant selected a picture that was not the US but that had the same valence as the respective US (according to the individual rating), the participant was classified as valence-aware of the particular pairing.

5.3. Results

For all statistical tests, a $p-$value less than .05 was accepted as significant.

5.3.1. Manipulation Check and Contingency Awareness

On average, participants in the full-distraction group correctly responded to 83% ($SD = 8\%$) of the math equations. In the contingency-distraction group, the average percentage of correct responses increased from 53% ($SD = 11\%$) in trials 1-20, via 74% ($SD = 7\%$) in trials 21-40, to 85% ($SD = 6\%$) in trials 41-60, indicating that they successfully learned the irrelevant picture-number contingencies.

Subjects' awareness of the US valence and the US identity is shown in Table 6.1. A 3 (group) $\times$ 2 (US valence) mixed-factors ANOVA revealed that valence awareness differs significantly between groups, $F(2, 106) = 59.09; p < .001$. There was no significant main effect of US valence, $F(1, 106) = 1.94; p = .17$, and no interaction, $F(2, 106) = 0.34; p = .71$. Another ANOVA on identity awareness revealed a main effect of group, as well, $F(2, 106) = 147.56; p < .001$. Again, there was no main effect of US valence, $F(1, 106) = 2.05; p = .16$, and no interaction, $F(2, 106) = 1.83; p = .17$.

Additional t-tests revealed that valence awareness in the attention-enhanced group differed significantly from both the full-distraction group, $t(75) = 12.42; p < .001$ and the contingency-distraction group $t(68) = 8.20; p < .001$. There was no significant difference in valence awareness between the two distraction groups, $t(69) = 1.91; p = .06$. Likewise, identity awareness in the attention-enhanced group differed significantly from both the full-distraction group, $t(75) = 18.76; p < .001$ and the contingency-distraction group $t(68) = 12.68; p < .001$. However, it was significantly greater in the contingency-distraction group than in the full-distraction group, $t(69) = 2.80; p < .01$.

5.3.2. EC effects

As a measure of EC, pre-post difference were computed for each CS by subtracting the evaluative ratings in the baseline phase from those obtained in the test phase. Mean subjective rating differences are shown in Table 5.1. A 3 $\times$ 2 mixed-factors ANOVA on the rating differences revealed a significant main effect of US valence, $F(1, 106) = 4.78; p < .05$, and, more importantly, a significant interaction between US valence and group, $F(2, 106) = 3.25; p < .05$. Additional paired t-tests within groups revealed a significant EC effect only in the attention-enhanced group, $t(37) = 3.58; p < .001$, but neither in the full-distraction group, $t(38) = 0.09; p = .93$, nor in

Table 5.1.: Mean contingency awareness and mean subjective rating differences (EC) of CS pictures that were paired with a liked or a disliked US (standard deviations in parentheses).

	Group		
	Attention Enhanced ($n = 38$)	Contingency Distraction ($n = 32$)	Full Distraction ($n = 39$)
Valence awareness[a]			
liked US	2.95 (0.32)	1.81 (0.93)	1.46 (0.85)
disliked US	2.97 (0.16)	1.94 (0.95)	1.64 (0.78)
Identity awareness[a]			
liked US	2.95 (0.32)	0.97 (0.98)	0.64 (0.71)
disliked US	2.92 (0.48)	1.25 (0.78)	0.64 (0.77)
Subjective rating differences			
liked US	0.31 (2.03)	−0.54 (2.05)	−0.06 (1.73)
disliked US	−0.91 (2.46)	−0.67 (2.43)	−0.09 (1.78)

[a] Mean number out of 3 CS-US pairings, that a subject was valence/identity-aware.

the contingency-distraction group, $t(31) = 0.25; p = .80$.

An EC score was computed by multiplying each pre-post rating difference with the respective US valence index (1 = liked US; −1 = disliked US). The EC score was significantly stronger in the attention-enhanced group than in the full-distraction group, $t(75) = 2.64; p < .05$. The difference in EC between the attention-enhanced group and the contingency-distraction group was marginally significant, $t(68) = 1.87; p = .07$ (two-tailed). There was no difference in EC, however, between the two distraction groups, $t(69) = 0.18; p = .86$.

5.3.3. Contingency Awareness and EC

The EC score was weakly but significantly correlated with both valence awareness, $r = .23; t(107) = 2.42; p < .05$, and identity awareness $r = .22; t(107) = 2.31; p < .05$.

The data of the distraction groups were split into valence-aware and valence-unaware items. In the contingency-distraction group, US valence did neither affect the rating differences of unaware items, $t(43) = 0.77; p = .22$, nor that of aware items, $t(57) = -0.20; p = .58$. In the full-distraction group, there was no effect for unaware items either, $t(68) = 0.83; p = .80$, but there was a marginally significant EC effect for aware items, $t(68) = 1.62; p = .05$. There were not enough unaware items in the attention-enhanced group to perform a statistical test. The EC effect in this group was significant when only aware items were included, $t(74) = 2.40; p < .01$.

To test the mediating role of contingency awareness on the effect of the manipulation on EC, a mediation analysis (Baron & Kenny, 1986) was conducted with awareness manipulation (attention-enhanced vs. distraction[3]) as the independent variable, contingency awareness (valence awareness) as the mediator and the EC score as the dependent variable. The manipulation significantly predicted the size of the EC score, $\beta = 0.57; t(107) = 2.55; p < .05$, and it also influenced the level of contingency awareness, $\beta = 0.42; t(107) = 10.42; p < .001$. Further, the size of the EC score increased with the level of contingency awareness $\beta = 0.88; t(107) = 2.31; p < .05$. Finally, there was an indirect effect of group on EC via contingency awareness, Sobel's $Z = 2.26; p < .05$. Thus, contingency awareness seems to mediate the impact of the distraction on the magnitude of EC.

5.4. Discussion

As indicated by the main effect of US valence, the present paradigm produced a robust effect of EC. The liking of previously neutral pictures changes as a result of pairing them with liked or disliked stimuli. This effect, however, can be ascribed mainly to those participants who were instructed to memorize the CS-US contingencies, i.e. to the attention-enhanced group. By contrast, both distraction tasks interfered with EC. In opposition to what has been reported by Fulcher and Hammerl (2001) and Hammerl and Fulcher (2005, but see Field & Moore, 2005), the present results imply that contingency awareness does not eliminate but rather produces EC.

However, can the occurrence of EC in the attention-enhanced group actually be attributed to the acquisition of contingency awareness? In order to memorize the contingencies, participants in this group might have attended not only to the contingencies but also to the pictures more than participants in the contingency-distraction

[3]The contingency distraction group and full distraction group were pooled for this analysis since both distraction tasks were designed to reduce contingency awareness.

group. Differences in EC could thus also be due to differences in the depth of processing with respect to the pictures (more resources might be needed to learn picture-picture associations than to learn picture-number associations). The results of the mediation analysis, however, strongly suggest that the differences were produced by contingency awareness (as measured by the recognition test). The secondary tasks were shown to affect the magnitude of EC through their differential impact on contingency awareness which is supposed to require attention being paid to the contingencies. Furthermore, even participants in the full-distraction group showed an EC effect with respect to individual CSs if they had recognized the respective CS-US contingencies. This pattern of results implies that both distraction tasks interfered with EC by preventing the participants from attending to the contingencies and from acquiring contingency awareness.

In line with previous findings, the data show that EC occurs only if the participant reached awareness of the CS-US contingencies (e.g. Pleyers et al., 2009; Stahl & Unkelbach, 2009), and only for those stimulus contingencies that a subject was aware of (Pleyers et al., 2007). Additionally, the mediation analysis showed that differences in EC between groups were produced by contingency awareness. Furthermore, EC effects were found in those CSs of which a participant was not able to recall the identity but only the valence of the contingent US. Thus, like in previous studies, valence awareness appears to be sufficient for EC to occur (Stahl et al., 2009, at least if EC is measured by means of subjective ratings). All these findings imply that contingency awareness is crucial in EC.

The main purpose of the study was to investigate the role of the specific focus of attention on EC. Since both distraction tasks eliminated conditioning, the results seem to replicate the finding that EC does not occur when attention is diverted during the acquisition (Field & Moore, 2005; Pleyers et al., 2009). EC seems to require attentional resources (Pleyers et al., 2009). In addition to these studies, the present results suggest that it is crucial to attend to the contingency. It turned out that keeping the focus of attention on the stimuli of interest (i.e. the CS and the US), does not preserve EC when attention is diverted from the CS-US contingency. Interestingly, the degree to which participants were contingency-aware (valence awareness) did not differ between the contingency-distraction and the full-distraction group. Thus, focusing attention to the stimuli did not foster the acquisition of contingency knowledge. This suggests that the distraction tasks used in the present study have modulated the focus of attention independently of contingency awareness. Admittedly, the focus of attention was not measured in a direct way. The secondary task performance data, however, indicate that subjects were engaged in the tasks and focused their attention either to the CSs and the USs or to the math equations. It would be interesting though to also directly measure the focus of attention during conditioning in future studies, e.g. bye means of eye-tracking in case of visual stimuli.

The results imply that EC depends on a contingency focus during conditioning which in turn is supposed to enable the participant to memorize the contingencies and become contingency-aware. In contrast to the conclusions drawn by Field and Moore (2005), the present results further suggest that focusing attention to the stimuli is not sufficient for EC to occur. Admittedly, this conclusion is based on a null effect, i.e. the diversion of attention from contingency eliminated EC. This, of course, is due to the fact that a task that diverts attention from the stimuli while focusing it to the contingency appears to be difficult to arrange empirically and would be even theoretically impossible when assuming that a stimulus focus is necessary for attending to the contingency between the stimuli. Further, it appears unlikely that the absence of EC is just a chance effect since the statistical power $(1 - \beta)$ to obtain a significant medium effect of EC ($d = 0.52$; see Hofmann et al., 2010) with 32 subjects in the contingency distraction group is .89. Moreover, EC effects were found also in the full-distraction group when the participant acquired awareness of the respective CS-US contingency. This indicates that the absence of EC is not due to chance but a result of the attentional distraction which suppressed EC.

Thus the data suggest that merely focusing attention to the CS and the US does not produce EC when preventing subjects from focusing to and learning the contingencies. Related to this finding, a recent study has shown that EC also depends on another dimension of the focus of attention, i.e. the valence focus (Gast & Rothermund, 2011). EC occurred only if the task required the participants to focus on valence but not if they were attending (only) to other stimulus properties (e.g. age). Thus, in addition to the contingency focus, it seems to be crucial whether attention has been assigned to the valence dimension. It would be interesting whether both a contingency focus and a valence focus are necessary for EC to occur or whether these are different ways to produce EC. According to the propositional account (e.g.

Mitchell et al., 2009), for instance, EC could result from propositions either about the CS-US contingency or about the valence of the CS.

To summarize, a method was presented that successfully modulated the focus of attention by means of specifically demanding secondary tasks. The results imply that EC occurs if the subject focuses attention not only to the stimuli but also to the contingencies between stimuli. Additionally, EC was found only if the participant reached awareness of the contingencies. Thus, the data are in conflict with two assumptions that have been raised in the literature being (a) that there is a dissociation between EC and contingency awareness (e.g. Fulcher & Hammerl, 2001), and (b) that attention (being paid to the stimuli) rather than contingency awareness is critical for EC to occur (Field & Moore, 2005). EC seems to require a specific contingency focus of attention which is assumed to foster the acquisition of contingency awareness. Though attention is supposed to be necessary, EC does not occur when the subject is not attending to the contingencies. This is in line with the assumption that EC is sensitive to both attentional resources and contingency awareness (Pleyers et al., 2009). Finally, the data are in line also with the assumption that contingency awareness moderates the acquisition of EC (Hofmann et al., 2010).

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Appendix

Instructions

Instructions given to the attention-enhanced group prior to the conditioning phase (translated from German)

In order to simulate an everyday situation (e.g. passing several advertisements during a shopping tour), you will now see some of the ads repeatedly. Thereby, two pictures will always be presented consecutively. Please try to memorize as many of those pairings as possible. At the end of the experiment, you will be required to recall these pairings. Please contact the tutor now if you have any questions or press a key to start the task.

Instructions given to the contingency-distraction group prior to the conditioning phase (translated from German)

In order to simulate an everyday situation (e.g. passing several advertisements during a shopping tour), you will now see some of the ads repeatedly. A prototypical task in such a situation might be to remember certain product numbers. Therefore, we assigned a certain number (1, 2 or 3) to each of the pictures. Your task is to figure out the numbers belonging to each of the pictures. Please press the respective key on the numeric pad whenever a picture appears on the screen. Of course, you will have to guess in the beginning. After having pressed a key, a feedback will be presented telling you whether the number was correct or not. Each picture will only be presented shortly. So please try to press a key quickly. Please contact the tutor now if you have any questions or press a key to start the task.

Instructions given to the full-distraction group prior to the conditioning phase (translated from German)

In order to simulate an everyday situation (e.g. passing several advertisements during a shopping tour), you will now see some of the ads repeatedly. A prototypical task in such a situation is to perform mental arithmetics (e.g. adding prices). Therefore, several math equations will be presented next to the pictures. Your task is to decide whether the equations are true or false. Please press "1" if the equation is false and press "3" if the equation is correct. A new equation will appear approximately every 8 seconds. Please solve the new equation even if you did not yet give a response to the previous one. Please try to work as quickly and accurately as possible. After having pressed a key, a feedback will be presented telling you whether your response was correct or wrong. Please try to watch the pictures simultaneously and keep your gaze on the screen in order to avoid missing an equation. Please contact the tutor now if you have any questions or press a key to start the task.

6. Manuscript B

Kattner, F. & Ellermeier, W. (2011). *Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning.* Manuscript submitted for publication.

Abstract

Evaluative conditioning refers to a change in the liking of a stimulus as a result of pairing it with an affective stimulus. Three verbal evaluative conditioning experiments addressed the role of the (phonological) working memory resources available during acquisition. In experiments 1 and 2, participants were either producing or listening to irrelevant speech while memorizing CS-US word pairs. As a within-subjects control, other pairs were presented in silence. While reliable evaluative conditioning was observed in silence, particularly the articulation of irrelevant speech impaired both contingency memory and conditioning. In experiment 3, working memory resources were disrupted in a more passive way by playing back irrelevant speech and different non-speech sounds. As expected, merely listening to irrelevant speech also interfered both with contingency awareness and evaluative conditioning. These results show that the acquisition of new evaluative responses requires working memory resources and challenge the assumption that evaluative learning is driven by automatic processes. Item-based analyses of recognized and non-recognized CS-US pairings revealed, however, that conditioning was not restricted to contingency-aware pairings. This implies that, though working-memory resources are needed to encode the CS-US contingencies, evaluative learning does not necessarily depend on the acquisition of explicit contingency knowledge.

Key words: evaluative conditioning; working memory; contingency awareness; irrelevant sound effect; contingency memory

6.1. Irrelevant speech prevents learning: On the importance of working memory for evaluative conditioning

Evaluative conditioning (EC) refers to a change in the valence of a stimulus that is induced by pairing it (the conditioned stimulus; CS) with an either liked or disliked stimulus (the unconditioned stimulus; US). Typically, the valence of the CS assimilates the valence of the US (see Martin & Levey, 1978; De Houwer, Thomas, & Baeyens, 2001; De Houwer, Baeyens, & Field, 2005, for reviews). The effect can be explained in terms of Pavlovian conditioning the dependent measure being a change in the evaluative response to the CS (De Houwer, 2007). Though researchers have been interested in various forms of EC for several decades (e.g. Razran, 1954; Levey & Martin, 1975; Stuart, Shimp, & Engle, 1987; Baeyens, Eelen, & Van den Bergh, 1990; Hammerl & Grabitz, 2000; Dickinson & Brown, 2007), the exact processes involved in the acquisition of EC are still poorly understood (e.g. De Houwer et al., 2005). Particularly, the role of cognitive factors (controlled processes) like contingency awareness or attentional resources during conditioning are discussed controversially (e.g. Field & Moore, 2005; Lovibond & Shanks, 2002).

Some researchers consider EC to be based on an automatic process of association formation that does not necessarily depend on the availability of attentional resources or awareness (e.g. Fulcher & Hammerl, 2001a; Martin & Levey, 1994; Walther & Langer, 2008). This conclusion is supported by reports of EC in subjects who were unaware of the stimulus contingencies (Baeyens et al., 1990; Dickinson & Brown, 2007; Hammerl & Fulcher, 2005; Walther & Nagengast, 2006). Furthermore, there are studies that actively limited cognitive resources by having the participants work on a secondary task during conditioning. Whereas distraction during Pavlovian conditioning was consistently shown to reduce both contingency awareness and the extent of conditioned (electrodermal) responses (e.g. Dawson, 1970; Dawson & Biferno, 1973), actively limiting the participants' attentional resources did not always eliminate EC (Hammerl & Grabitz, 2000; Fulcher & Hammerl, 2001b). Since the distraction task reduced the participants' contingency awareness compared to an awareness-induced group, the authors concluded that EC cannot rely on contingency knowledge[1]. Perhaps even more convincing instances of unaware EC are provided by experiments with subliminally presented USs (using backward masking, e.g. De Houwer, Baeyens, & Eelen, 1994; De Houwer, Baeyens, & Hendrickx, 1997; Field & Moore, 2005). Since subjects were unable to identify the stimuli themselves, it is unlikely that they acquired contingency knowledge[2].

By contrast, others assume EC to rely on contingency awareness or attentional processing of the stimulus associations (e.g. Pleyers, Corneille, Luminet, & Yzerbyt, 2007; De Houwer, 2007; Stahl, Unkelbach, & Corneille, 2009). Recently, EC effects were found to be significantly smaller or even eliminated in subjects that were not aware of the stimulus contingencies (Dawson, Rissling, Schell, & Wilcox, 2007) or when attention was diverted by means of secondary tasks (Field & Moore, 2005; Pleyers, Corneille, Yzerbyt, & Luminet, 2009). Additionally, it has been shown that, within subjects, EC is restricted to those CSs of whose respective USs the participant has become aware of (Dawson et al., 2007; Pleyers et al., 2007; Stahl & Unkelbach, 2009; Wardle, Mitchell, & Lovibond, 2007). Stahl et al. (2009), however, demonstrated that awareness of the valence of the US (rather than of its identity) is sufficient for EC to occur. Similarly, Gast and Rothermund (2011) found EC to occur only if the secondary task to be performed during conditioning focused subjects' attention on the valence dimension.

These findings clearly support the assumption that EC depends on the availability cognitive resources during conditioning. Although there are studies that convincingly demonstrated EC in the absence of awareness, a recent meta-analysis of evaluative learning identified contingency awareness to be an important factor determining the magnitude of EC (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). There is only weak evidence for EC in subjects who are not aware of the stimulus contingencies (but see C. R. Jones, Olson, & Fazio, 2010) However, if EC depends on contingency knowledge, then the encoding of the CS-US contingencies should be crucial. Particularly, during the acquisition, representations of the CS and the US are expected to occupy working memory resources. Consistent with this idea,

[1] Occasionally, even a reversal of the conditioning effect was reported when contingency awareness was induced experimentally (Fulcher & Hammerl, 2001b; Hammerl & Fulcher, 2005).

[2] It is still unclear, however, why EC could not yet be found reliably after subliminal presentations of the CS (unpublished data mentioned by Öhman, 1988).

Brunstorm and Higgs (2002) found EC to be diminished when participants were performing a counting task during conditioning and the authors concluded that EC is sensitive to attentional constraints on working memory. In addition to this effect, the present study intends to explore the role of encoding the stimulus pairings during conditioning in more detail, by actively limiting working memory capacity. To that effect, different grades of working memory disruption were produced within subjects. If EC relies on the processing of CSs and USs in working memory, then it should vary with the availability of working memory resources.

To accomplish this, we developed a paradigm to limit the phonological working memory capacity in a verbal conditioning procedure (similar to C. K. Staats & Staats, 1957). However, the subjects' task was to memorize the CS-US pairs while listening to or uttering irrelevant speech that is assumed to impair the encoding of the verbal materials in working memory. Thereby, a situation much like in the *irrelevant sound paradigm* (e.g. Colle & Welsh, 1976; Salamé & Baddeley, 1982; D. M. Jones & Macken, 1993) is created, according to which the presentation of task-irrelevant speech (or other sounds such as changing tones) reliably impairs performance on serial recall and (to a lesser extent) other memory processes like pair-associate learning. The acoustic properties moderating the distraction effect are so well understood by now (see Banbury, Macken, Tremblay, & Jones, 2001; Hughes & Jones, 2001, for reviews) that it appears reasonable to generate irrelevant sound sequences that produce distinct, and well-defined degrees of memory impairment. Stationary, continuous noise, for example does not produce any change in performance compared to a quiet control condition (e.g. Ellermeier & Zimmer, 1997; D. M. Jones, Miles, & Page, 1990; Salamé & Baddeley, 1982). Free-running speech, by contrast, has been shown to generate strong decrements in recall, while sequences of intermittent tones changing in frequency typically produce intermediate levels of memory impairment (e.g. D. M. Jones & Macken, 1993; Klatte, Kilcher, & Hellbrück, 1995; LeCompte, Neely, & Wilson, 1997; Salamé & Baddeley, 1989; K. Zimmer, Ghani, & Ellermeier, 2008).

There are different theoretical accounts on how the presence of irrelevant sound should affect the encoding of CS-US pairings, and thus contingency knowledge. The 'phonological loop' model (Baddeley, 1986, 2003) suggests that participants will phonologically encode the CS-US pairs for rehearsal. Simultaneously presented irrelevant sound is bound to gain automatic access to the same memory module thus competing for the limited capacity of the phonological store and rehearsal mechanism. The 'object-oriented episodic record' (O-OER) model (D. M. Jones, 1993; D. M. Jones, Beaman, & Macken, 1996; Macken & Jones, 1995), on the other hand, postulates that the pre-attentively registered serial information perceived in the irrelevant auditory stream will interfere with serial learning of the to-be-remembered word pairs by degrading the links between items rather than the memory trace of the items themselves. Both models would predict that distraction by irrelevant auditory material during conditioning should also reduce contingency memory either - according to the phonological loop model - depending on how speech-like (i.e. suited for phonological encoding) it is, or - according to the O-OER model - as a function of the amount of 'changing-state' information present in the irrelevant sound.

Another option for disrupting phonological short-term memory is to have subjects exercise *articulatory suppression*, e.g. by making them repeatedly utter a string of syllables (Baddeley, Lewis, & Vallar, 1984). The major difference is that the irrelevant materials are produced rather than merely processed by the subjects. The 'phonological loop' model suggests that articulatory suppression is even more effective in disrupting the encoding of phonological items in working memory. Indeed, Neath, Farley, and Surprenant (2003) report that the magnitude of disruption produced by articulatory suppression is about twice that of irrelevant speech. In contrast to the 'phonological loop' model, however, the O-OER model does not predict different levels of distraction when comparing articulatory suppression and irrelevant speech in a serial learning task (Macken & Jones, 1995).

Thus, in order to generate different degrees of working memory disruption during EC (and within subjects), participants had to memorize verbal CS-US pairs while different types of either speech-like or changing-state sounds were presented, or while they were required to continuously articulate irrelevant words. If the availability of working memory resources during the acquisition is critical for EC to occur, then the extent of learning should vary with these modulations. In addition, it is assumed that the different experimental conditions go along with distinguishable levels of contingency awareness, i.e. increasing phonological distraction is expected to gradually impair the acquisition of contingency memory. Fulcher and Hammerl (2001a) argue that if there is a causal relationship between contingency awareness and evaluative learning, then EC should increase when awareness is enhanced and it should decrease when awareness is reduced. By measuring contingency memory on the level of word pairs that were learned under different conditions of distraction (i.e. using an item-based analysis of awareness, see Pleyers et al., 2007), the present study also intends to contribute to the debate on the role contingency awareness in EC.

6.2. Experiment 1

The main purpose of experiment 1 is to establish an effect of phonological distraction during evaluative learning. Therefore, we compared the impact of no distraction with that produced by irrelevant speech and articulatory suppression. Different pairings of neutral non-words and either positive or negative words were presented in silence, concurrent with the playback of irrelevant speech, or while the subject were exercising articulatory suppression. Both irrelevant speech and articulatory suppression are supposed to impair the encoding of the verbal CSs and USs in working memory. If working memory capacity is crucial to EC, then both types of disruption should interfere. As a consequence of poorer encoding, also contingency knowledge (measured by recognition performance after conditioning) is expected to be lower in the phonological distraction conditions, as well. Furthermore, the 'phonological loop model' predicts a stronger impact of articulatory suppression on contingency knowledge compared to passively registered irrelevant speech.

6.2.1. Method

Participants

A total of twenty-nine participants (26 female) between 19 and 40 years of age ($M = 22.7; SD = 5.4$) were recruited from the campus of Technische Universität Darmstadt. The majority were first-year students of psychology and none of them understood or spoke Korean (the language of the irrelevant speech). Each participant was tested individually in sessions of about 35 minutes.

Stimuli and apparatus

Fifty three-syllable non-words were generated by substituting or adding random vowels to existing German male and female first names. For instance, the non-word

'Aguarg' was derived from the name 'Georg'[3]. Based on the baseline ratings made by each subject, the most neutral of these non-words were used as CSs (see procedure).

Nine extremely positive and nine extremely negative German 3-syllable nouns from the Berlin Affective Word List (BAWL; Vo, Jacobs, & Conrad, 2006) served as positive and negative USs. Mean emotionality ratings of positive and negative nouns were $2.20(SD = 0.82)$ and $-2.24(SD = 0.73)$, respectively.

The experiment was run in a single-walled sound-attenuated listening room (IAC). Visual stimuli (the non-words) were presented on a 19" TFT monitor (Philips) and the distracting sounds were presented via headphones (Beyerdynamics DT-990). Stimulus presentation and evaluative response measurements were controlled by a Matlab program, using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997).

Design and Procedure

A 2 (US valence) $\times$ 3 (phonological distraction) design was implemented with repeated measures on both factors. Subjects were told the purpose of the experiment was to find appropriate liked and disliked names for the characters in a new comic strip.

In the baseline phase subjects were required to rate each non-word (the potential comic characters' names) by means of a 21-category scale (ranging from -10 to $+10$). The non-words were presented successively in randomized order. Subjects were encouraged to make quick and spontaneous responses. The first 10 ratings were used for training and not considered in the following phases. Based on the remaining 40 baseline ratings, those 18 non-words the ratings of which fell closest to zero were selected to be used as CSs. Each CS was randomly assigned to an either positive or negative word from the BAWL.

In the acquisition phase, subjects were told to learn pairings of names (i.e. some of the non-words) and surnames (i.e. the BAWL words). Six CS-US pairings (3 with a positive and 3 with a negative US) were presented in silence, another six were presented together with irrelevant speech and during still another six pairings

[3]In a pilot study ($N = 6$) the names were rated by independent raters with respect to pleasantness ($M = -0.8; SD = 2.4$; -10 = very unpleasant, +10 = very pleasant) and the presumed gender ($M = -2.1; SD = 3.9$; -10 = certainly male, +10 = certainly female), indicating sufficient variance between stimuli. Further, the ratings of pleasantness were not correlated with the gender ratings ($r = .09, n.s.$).

the participants were required to continuously articulate the German words 'drei-vier-fünf' ('three-four-five'). In each case, three pairings of each US valence were combined with a particular distraction condition. These 18 pairings (3 pairings per US valence × distraction condition) were presented six times each in randomized order. Thus, a total of 108 trials was presented. The CSs and the USs were presented for 1 s, separated by a trace interval of 0.5 s. The inter-trial interval was 6 s. Free-running speech (a segment of a Korean poem recited by a male native speaker) was used as the distraction sound played back in the irrelevant speech trials (adopted from K. Zimmer et al., 2008). Unknown foreign speech was used to avoid any affective impact on the stimulus pairings due to the semantic content of the utterances. The speech was presented at an RMS level corresponding to approximately 63 dB SPL. A text message was displayed on the screen in each trial telling the subjects whether they had to speak (in case of an articulatory suppression trial) or not (in case of silence or irrelevant speech trials). The participants' task was to learn the assumed name-surname pairings and to ignore the speech. They were told that the purpose was to find out which compound names could be most easily memorized.

Subsequently, in the test phase, each non-word was rated a second time using the same procedure as in the baseline phase. Finally, contingency awareness was assessed by means of a forced-choice recognition test. Each CS-US pair was displayed together with five randomly-assigned pairs each consisting of a non-word and a word (which had been used as CSs or USs in different combinations during the acquisition phase) and the subjects had to choose the respective CS-US pair by clicking on it. To minimize the probability of false 'unaware' classifications, subjects were encouraged to guess whenever they were not sure.

At the end of the experiment, each subject was given a sheet of paper containing several questions to assess the participants' demand awareness. They had to specify, for instance, what they thought the actual purpose of the study was, and whether they felt being expected to behave in a certain way.

According to this final demand-awareness questionnaire, no subject was identified to be aware of the purpose of the study.

6.2.2. Results

For all tests in experiments 1, 2, and 3, a p-value of less than .05 was accepted as significant.

Evaluative conditioning

Mean evaluative ratings of CS non-words before and after the conditioning phase are illustrated in figure 6.1. Evaluative rating differences were computed by subtracting the baseline ratings of each CS from those obtained after conditioning. A 2 (US valence) $\times$ 3 (phonological distraction) repeated-measures ANOVA on these rating differences revealed a significant main effect of US valence, $F(1, 28) = 6.25; p < .05$. However, its interaction with phonological distraction was not significant, $F(2, 56) = 0.23; p = .79$. There was also no main effect of phonological distraction, $F(2, 56) = 0.03; p = .97$.

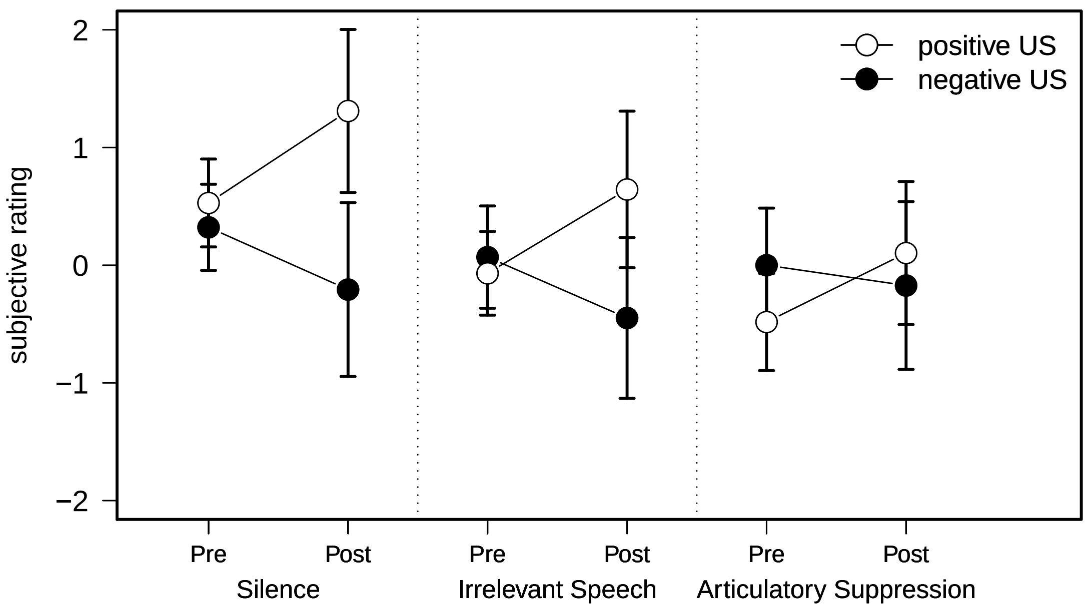

Figure 6.1.: Evaluative ratings of non-words that were paired with positive or negative words either in silence or under conditions of irrelevant speech or articulatory suppression (experiment 1).

In addition, contrasts were computed within the phonological distraction conditions. Paired t-tests revealed marginally significant EC effects in the silence condition, $t(28) = 2.01; p = .05; d = 0.47$, and in the irrelevant speech condition, $t(28) = 2.09; p < .05; d = 0.47$, but there was no significant EC effect in the articulatory suppression condition, $t(28) = 1.00; p = .33; d = 0.28$.

Table 6.1.: Contingency memory in experiment 1 (in percentage correct, standard deviations in parentheses).

	Phonological distraction condition		
	silence	irrelevant speech	articulatory suppression
negative US	90.8 (29.1)	92.0 (27.3)	82.8 (38.0)
positive US	70.1 (46.0)	74.7 (43.7)	63.2 (48.5)

Contingency memory

Contingency memory, i.e. the percentage of correctly recognized CS-US pairings, can be seen in table 6.1. Another 2 (US valence) $\times$ 3 (distraction condition) repeated-measures ANOVA on contingency memory revealed a highly significant main effect US valence, $F(1, 28) = 22.82; p < .001$. Even though recognition scores are nearly 10% lower in the articulatory suppression condition, the main effect of phonological distraction on recognition memory failed to reach statistical significance, $F(2, 56) = 3.08; p = .05$. There was no significant interaction $F(2, 56) = 0.14; p = .87$.

Contingency memory and evaluative conditioning

The impact of contingency knowledge on EC was analyzed on an item level. Therefore, the data were divided into those items that were recognized in the awareness test and those that were not. For aware items (412 of a total of $29 \times 18 = 522$ items), the rating differences were $M = -0.37 (SD = 4.18)$ in case of disliked USs and $M = +0.82 (SD = 4.14)$ in case of liked USs. This difference was statistically significant, $t(28) = 3.27; p < .01$ (paired t-test). For non-recognized items (110 items), the mean rating difference of CSs paired with disliked USs was $M = -0.67 (SD = 4.29)$ whereas the rating difference of CSs paired with liked USs was $M = +0.40 (SD = 3.95)$. However, this difference was not significant, $t(36) = 0.65; p = .52$ (two-sample t-test).

6.2.3. Discussion

A significant EC effect was demonstrated in experiment 1: The liking of non-words that were paired with positive words increased, whereas the liking of non-words that were paired with negative words decreased. A more detailed analysis revealed that this effect was less robust when the subjects had to actively articulate numbers while the contingencies were presented than when they were presented in silence or when subjects were merely listening to speech. Whereas the active production of irrelevant speech appears to impair conditioning, the mere processing of irrelevant speech thus seems to have no effect.

Articulatory suppression also had its effect on contingency memory: Subjects' recognition of CS-US pairings was clearly worse in this condition compared to the silence or the irrelevant speech condition. Though the critical interaction between phonological distraction and US valence was nearly significant, we did not find a reliable effect of working memory modulations on EC, since irrelevant speech did not impair EC more than silence did. This might be due to a ceiling effect with respect to the level of contingency memory. Subjects' awareness of the contingencies might have reached a level that assures EC, even under conditions of working memory disruption. Replicating the results reported by Pleyers et al. (2007), the conditioning effects also appear to be restricted to those contingencies that subjects were aware of. However, since only a minority of contingencies were not recognized, the non-significant conditioning effect for the unaware items might also be due to a lack of statistical power.

Rather unexpectedly, US valence had an effect on contingency memory, as well, such that pairings with negative words were recognized much better than pairings with positive words. However, this effect is in line with valence asymmetries that have been reported in recognition memory tasks involving emotional stimuli (e.g. Orthony, Turner, & Antos, 1983; Ohira, Winton, & Oyama, 1998). The remarkable effect of US valence on contingency memory might have been facilitated by the semantic content of the words used. Moreover, CS-US parings containing semantic content are supposed to be much better recognizable in general than pairings without any semantic associations. This could also account for the high overall level of contingency knowledge in experiment 1. Therefore, we decided to conduct a second experiment in which the rather unfamiliar non-words served both as CSs and USs. By doing this, contingency memory is expected to be lower, thus avoiding a ceiling effect, and phonological distraction might be more effective in modulating the conditioning effect.

6.3. Experiment 2

In experiment 2, the same phonological distractions as in experiment 1 were used: CS-US pairings were either presented together with irrelevant speech or while subjects were exercising articulatory suppression. Control pairings were presented in silence. In order to reduce the overall level of working memory resources available during conditioning, the pair-associate learning task was made more difficult by only using non-words. By doing this, working memory modulations are expected to have a stronger effect on conditioning. While EC is expected to be maximally inhibited by articulatory suppression (like in experiment 1), we expect irrelevant speech to interfere with EC, to some extent, as well.

6.3.1. Method

Participants

Another forty participants (28 female) with ages between 19 and 39 years ($M = 22.6$; $SD = 4.2$) were recruited from the campus of Technische Universität Darmstadt and tested individually in sessions of about 35 minutes. Again, the majority were students and none of them understood or spoke Korean.

Stimuli and apparatus

The apparatus and the stimuli were the same as in experiment 2. However, both the CSs and the USs were selected from the pool of 50 non-words on the basis of individual baseline ratings made by each subject.

Design and Procedure

The experimental design and the procedure were identical to experiment 1 with the exception that (instead of meaningful words from the BAWL) those nine non-words with the highest and the lowest baseline ratings each were used as liked or disliked USs, respectively.

Again, no subject was identified to be aware of the purpose of the study.

6.3.2. Results

Evaluative conditioning

Mean baseline ratings of non-words that were used as liked and disliked USs were $+5.00$ ($SD = 1.82$) and -5.83 ($SD = 1.92$), respectively. Mean evaluative ratings of CSs before and after conditioning can be seen in figure 6.2.

A 2 (US valence) $\times$ 3 (phonological distraction) repeated-measures ANOVA revealed a significant main effect of US valence on the pre-post evaluative rating differences, $F(1, 39) = 4.72; p < .05$, confirming the overall EC effect. However, its interaction with auditory distraction was not significant, $F(2, 78) = 0.55; p = .58$. The type of phonological distraction also did not have a significant main effect on the rating difference, $F(2, 60) = 0.77; p = .47$.

In addition, contrasts were computed within the phonological distraction conditions. Paired t-tests revealed a significant EC effect within the silence condition, $t(39) = 1.90; p < .05; d = 0.40$, but neither within the irrelevant speech condition, $t(39) = 1.26; p = .11; d = 0.25$ nor within the articulatory suppression condition, $t(39) = 0.42; p = .34; d = 0.08$.

Contingency memory

Mean recognition performance of stimulus pairings that were presented under different conditions of auditory distraction can be seen in table 6.2. Collapsed across US valence, subjects correctly recognized 57.5% of the non-word pairings that were learned in the silence, 51.3% of those learned under irrelevant speech, and 45.4% of those in the articulatory suppression condition. A 2 (US valence) $\times$ 3 (phonological distraction) repeated-measures ANOVA revealed a significant main effect of phonological distraction on contingency awareness, $F(2, 78) = 6.67; p < .005$, reflecting the monotonic decrease in recognition performance from silence over irrelevant speech to articulatory suppression. In addition, a significant main effect of US valence was found, $F(1, 78) = 18.19; p < .001$, with the disliked-US pairings being memorized better than the liked-US pairings. There was no significant interaction, $F(2, 78) = 2.09; p = .13$.

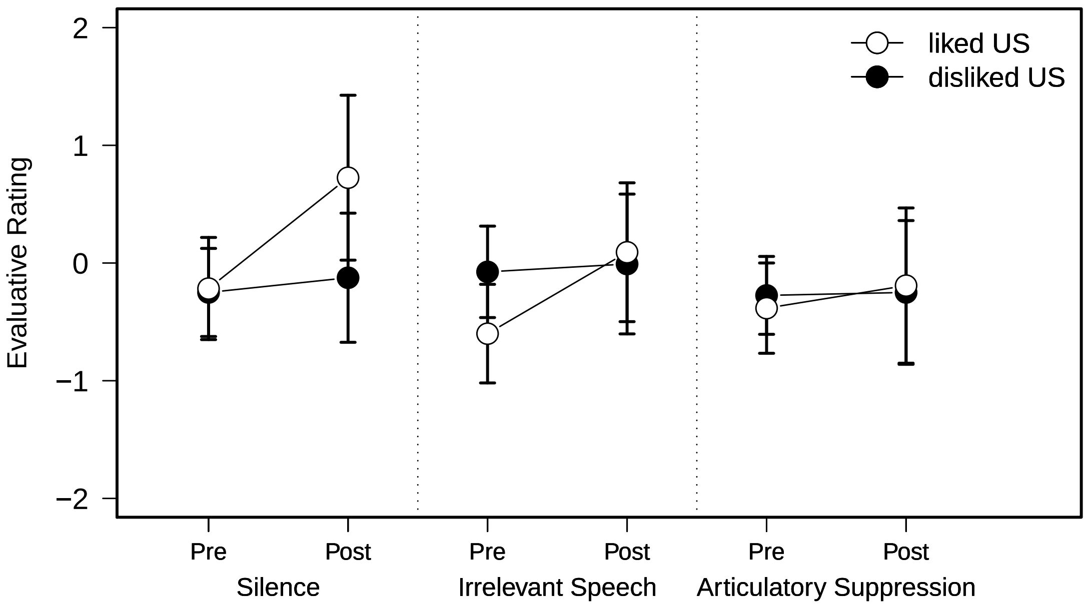

Figure 6.2.: Evaluative ratings of non-words that were paired with liked or disliked non-words either in silence or under conditions of irrelevant speech or articulatory suppression (experiment 2).

Contingency memory and evaluative conditioning

The impact of contingency awareness on EC was analyzed on an item level. To that effect, the data were divided into those items that were recognized in the awareness test and those that were not (see table 6.2). For aware items (370 items), the mean rating difference of CSs that were paired with a disliked or liked US were $M = +0.47$ ($SD = 3.81$) and $M = +0.78$ ($SD = 3.92$), respectively. This difference, however, was not significant, $t(77) = 0.56; p = .58$ (two-sample t-test). For the unaware items (350 items), the mean rating difference was $M = -0.53$ ($SD = 3.93$) in case of disliked USs and $M = +0.48$ ($SD = 4.12$) in case of liked USs. This difference was not significant, either, $t(73) = 1.65; p = .10$ (two-sample t-test).

Table 6.2.: Contingency memory (in percent correct) and evaluative rating differences of non-recognized and recognized CS-US pairings in experiment 2 (standard deviations in parentheses).

	Phonological disruption condition		
	silence	irrelevant speech	articulatory suppression
Contingency memory			
disliked US	63.3% (48.4)	58.3% (49.5)	59.2% (49.4)
liked US	51.7% (50.2)	44.2% (49.9)	31.7% (46.7)
Evaluative rating differences (non-recognized pairings)			
disliked US	−0.73 (3.51)	−0.70 (4.17)	−0.18 (4.07)
liked US	+1.09 (4.18)	+0.40 (3.79)	+0.12 (4.33)
Evaluative rating differences (recognized pairings)			
disliked US	+0.62 (4.26)	+0.61 (3.66)	+0.17 (3.46)
liked US	+0.81 (4.39)	+1.06 (4.09)	+0.34 (2.75)

6.3.3. Discussion

Again, an overall evaluative conditioning effect was observed in experiment 2. Though the critical interaction with phonological distraction was not significant, both types of working memory disruptions, articulatory suppression and irrelevant speech, appear to reduce evaluative learning.

Further, the working memory modulations go along with a systematic decrease in contingency memory. As expected, CS-US recognition was best in the silence condition and worst in the articulatory suppression condition. This implies that, in line with the 'phonological loop' model, actively producing irrelevant speech leads to even stronger disruptions in working memory than merely processing irrelevant speech does. More importantly, however, we found an irrelevant speech effect on a delayed recognition measure of memory in a non-serial pair-associate learning task. Further, US valence again had a considerable impact on contingency memory. Replicating the valence asymmetry effect from experiment 1, pairs involving individually disliked non-words were recognized much better than those involving individually liked non-words.

There was no difference in EC between recognized and non-recognized CS-US pairings. Rather surprisingly, however, the conditioning effect within the silence condition appears to be more pronounced in unaware pairings which would be at odds with earlier findings (Pleyers et al., 2007). This finding suggests that, while working memory resources are necessary, the resulting contingency knowledge seems to be less important in the acquisition of EC. In other word, EC can occur in the absence of contingency awareness if sufficient working memory resources are available during conditioning. However, the effect of working memory modulations on EC does not appear to be robust enough since the critical interaction was not significant. Therefore, we tried to replicate the effect of irrelevant speech on conditioning in a third experiment with different phonological distraction conditions.

6.4. Experiment 3

In experiments 1 and 2, articulatory suppression was the distraction condition that impaired EC most dramatically. One might wonder whether these impairments of EC are actually due to reduced phonological working memory capacity or whether it is the dual-task situation created by the articulatory suppression trials that is responsible for the effect: In both previous experiments, subjects were required (a) to learn the contingencies and (b) to articulate numbers during the respective trials. To decide whether it is phonological disruption or the cognitive load produced by the dual-task situation, a third experiment was conducted without including the articulatory suppression condition. Instead, only passive phonological working memory disruption was produced. Different types of speech and non-speech background sounds were played back in experiment 3 not requiring the participants to actively engage in a secondary task. Thus, the participants' cognitive load during conditioning is expected to be stressed less than in the previous experiments since (a) mere passive auditory disruption is supposed to be less demanding than an active articulation task, and (b) subjects do not have to continuously monitor the instructing text messages any longer. Furthermore, in order to enhance contingency memory, we decided to make the pair-associate learning task easier by using fewer stimulus pairings (only 2 pairings per US valence $\times$ disruption condition). For that reason, more robust effects of EC than in experiment 2 are expected due to the availability of more working memory resources.

The purpose of experiment 3 was to produce different levels of working memory disruption during EC through the playback of three types of irrelevant sound that differed with respect to how speech-like they were and how much 'changing-state' information they contained: white noise, sinusoidally frequency-modulated (FM) tones and speech. According to the O-OER model, the working memory disruption produced by FM tones should be similar to that produced by speech because it provides a comparable amount of 'changing state' information. The phonological loop model, however, predicts that disruption by FM tones should more or less resemble that of white noise, since both are not speech-like.

Thus, similar to experiment 2, the impact of different types of passive phonological distraction on both contingency memory and evaluative learning was investigated by presenting either white noise, FM tones or speech while the participant is required to learn pairs of non-words. In contrast to the previous experiments, there should be no difference in the cognitive load produced by different distraction trials since the secondary articulation task was omitted.

6.4.1. Method

Participants

Another forty participants (20 female) with ages ranging between 18 and 55 years ($M = 24.1; SD = 6.7$) were recruited from the campus of Technische Universität Darmstadt. The majority were students and none of them understood or spoke Korean. Each participant was tested individually in a session of about 35 minutes duration.

Stimuli and apparatus

An enlarged stimulus set of 100 non-words was used in the baseline rating phase in order to obtain less variance in the initial CS ratings. Like in experiment 2, CSs and USs were selected on the basis of the individual baseline ratings.

Now, three types of distraction sounds were used to manipulate the subjects' ability to memorize the stimulus pairing during the acquisition phase (adopted from K. Zimmer et al., 2008): white noise, intermittent FM tones (with a 1150-Hz center frequency and a modulation depth of 850 Hz; modulated at a rate of 0.25 Hz and interrupted by 300-ms gaps of silence every 700 ms) and the segment of free-running speech from experiment 1 and 2. The sounds were presented at equal RMS levels corresponding to approximately 63 dB SPL. Onsets and offsets of all sounds were smoothed using 10-ms rise and fall times.

The apparatus was the same as in experiments 1 and 2.

Design and procedure

The design was the same as in the previous experiments. The procedure was identical expect for the following changes: Participants evaluated a total of 100 non-words in the baseline and test phase. In the acquisition phase, 12 pairings consisting of a neutral and either liked or disliked non-words (instead of 18 pairings as in the previous experiments) were presented 6 times each in randomized order while - together with 4 pairings each - either white noise, FM-tones or speech was played back. Thus two pairings of each US valence were combined with a particular distraction sound, and a total of 72 trials was presented.

According to the answers on the final sheet of paper, again, no subject was identified to be aware of the purpose of the study.

6.4.2. Results

Evaluative conditioning

Mean baseline ratings of liked and disliked USs were $6.60 (SD = 2.05)$ and $-7.39 (SD = 1.61)$, respectively. Mean evaluative ratings of CS non-words before and after conditioning can be seen in figure 6.3. On a descriptive level, evaluative learning was found for non-word pairings that were presented either together with white noise or FM-tones, but not for those presented together with irrelevant speech. A 2 (US valence) $\times$ 3 (phonological distraction) repeated-measures ANOVA on the pre-post evaluative rating differences revealed a significant main effect of US valence, $F(1, 39) = 11.00; < .01$, again confirming the overall EC effect. More importantly, a significant interaction between US valence and phonological distraction was found, $F(2, 78) = 3.58, p < .05$, confirming the impact of the working memory modulations (i.e. the irrelevant sound conditions) on EC. There was no main effect of phonological distraction on the evaluative rating differences, $F(2, 78) = 0.23; p = .80$.

Evaluative conditioning effects were further investigated within each auditory distraction condition by means of paired t-tests. Pre-post evaluative rating shifts differed significantly when contrasting CSs that were paired with liked or disliked USs

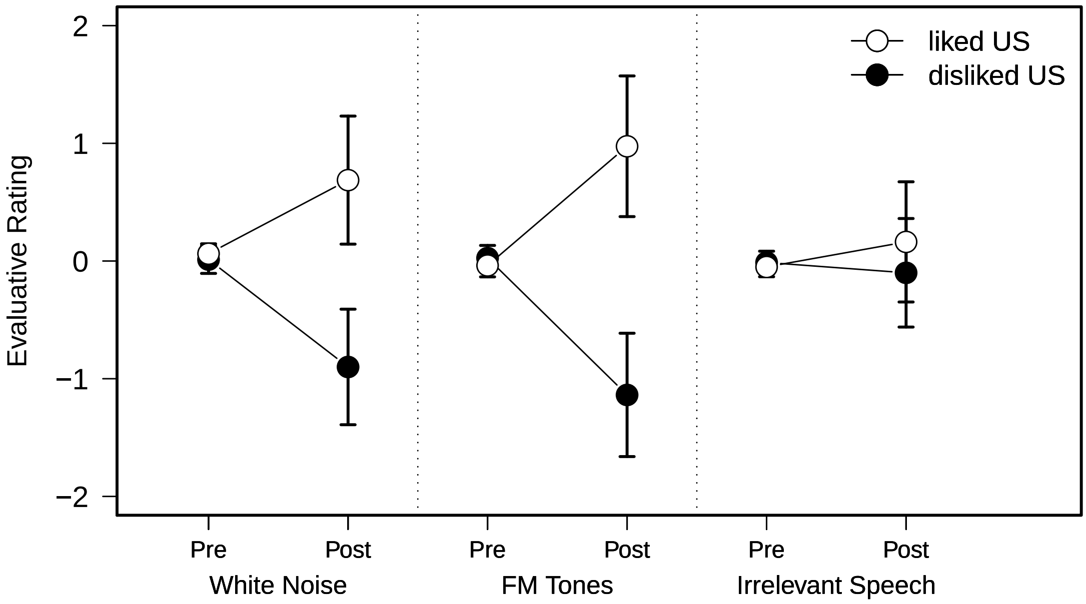

Figure 6.3.: Evaluative ratings of non-words that were paired with liked or disliked non-words under different irrelevant sound conditions (experiment 3).

within the noise condition, $t(39) = 2.52; p < .01; d = 0.61$, and within the FM tones condition, $t(39) = 3.72; p < .001; d = 0.75$, but there was no significant EC effect within the irrelevant speech condition, $t(39) = 0.57; p = .29; d = 0.12$.

Contingency memory

Contingency recognition data can be seen in table 6.3. On average, subjects correctly recognized 70.0% of the non-word pairings in the noise condition, 65.0% in the tones condition, and 51.2% in the speech condition. A 2 (US valence) × 3 (phonological distraction) repeated-measures analysis of variance (ANOVA) on pair recognition performance confirms the main effect of phonological distraction, $F(2, 78) = 6.67; p < .01$, showing that working memory was successfully disrupted (by irrelevant speech) during the acquisition. There was neither a significant main effect of US valence on recognition performance, $F(1, 39) = 0.86; p = .36$, nor an interaction with phonological distraction, $F(2, 78) = 0.26; p = .77$.

Table 6.3.: Contingency memory (in percent correct) and evaluative rating differences for recognized and non-recognized pairings in experiment 3 (standard deviations in parentheses).

	Phonological disruption condition		
	white noise	FM tones	irrelevant speech
Contingency memory			
disliked US	71.2% (45.4)	65.0% (48.0)	55.0% (50.1)
liked US	68.7% (46.6)	65.0% (48.0)	47.5% (50.3)
Evaluative rating differences (non-recognized pairings)			
disliked US	−0.13 (2.88)	−0.89 (3.48)	−1.11 (3.51)
liked US	−0.08 (2.81)	+0.46 (4.25)	+0.90 (2.71)
Evaluative rating differences (recognized pairings)			
disliked US	−1.23 (3.29)	−1.31 (3.42)	+0.75 (3.26)
liked US	+0.95 (3.47)	+1.31 (3.17)	−0.55 (3.16)

Contingency memory and evaluative conditioning

Again, the data were split into those items that were recognized in the awareness test and those that were not (see table 6.3). For aware items (298 items), the mean rating difference of CSs that were paired with a disliked or liked US was $M = -0.78$ ($SD = 3.12$) and $M = +0.40$ ($SD = 2.70$), respectively. This difference, however, failed to reach statistical significance, $t(77) = 1.78;:$ $p = .08$. For the unaware items (182 items), the mean rating difference was $M = -0.57$ ($SD = 2.73$) in case of disliked USs and $M = 0.69$ ($SD = 1.98$) in case of liked USs. This difference was significant, $t(66) = 2.18; p < .05$.

6.4.3. Discussion

The results of experiment 3 again demonstrate successful evaluative learning with verbal non-word stimuli. More importantly, phonological distraction during the acquisition phase modulated the magnitude of EC. While clear conditioning effects were found when non-speech sounds (FM tones, white noise) were played back during the encoding of the CS-US pairs, the concurrent presentation of speech practically abolished EC. Since irrelevant background speech is known to consume working memory resources, this result suggests that working memory plays a crucial role during the acquisition of EC.

The type of phonological distraction also reduced the degree of contingency knowledge. Listening to irrelevant speech impaired memorizing the CS-US pairs more than listening to FM tones which in turn reduced contingency knowledge more than white noise did. Thus contingency awareness was successfully modulated via phonological disruption of working memory in experiment 3. Different degrees of contingency memory were experimentally induced and, more importantly, the working memory modulations also affected evaluative learning.

However, since an increase in contingency knowledge did not go along with stronger EC effects (rather the opposite seems to occur), the data suggest that the resulting contingency knowledge (measured explicitly in a post-acquisition recognition test) is less critical for EC to occur than the availability of working memory resources during the acquisition.

6.5. General Discussion

The present study demonstrates reliable EC effects in a verbal conditioning paradigm with non-words serving as the CSs and either meaningful words or individually pre-rated non-words serving as the USs. The data thus document the robustness of EC even with rather unobtrusive non-word USs.

Phonological distraction was shown to interfere with the acquisition of EC. Whereas clear EC effects were observed for CS-US pairings that were presented in silence, or during the playback of noise or FM tones, EC diminished when participants were producing (in experiments 1 and 2) or listening to irrelevant speech (in experiment 3). This suggests that, in addition to attentional resources (Field & Moore, 2005; Pleyers et al., 2009), working memory capacity plays a crucial role in the acquisition of EC. Occupying working memory with irrelevant materials - as did diverting the focus of attention - impaired the acquisition of EC. This highlights the importance of the availability of cognitive resources during conditioning. Since EC appears to be sensitive to working memory modulations, the data challenge the assumption of evaluative learning being a mere referential automatic process which should be independent of higher-order cognitive processing (Baeyens, Eelen, Crombez, & Van den Bergh, 1992; Baeyens & De Houwer, 1995; Baeyens, Eelen, & Crombez, 1995; Fulcher & Hammerl, 2001b). Rather, the present data are in line with single-process models of associative learning or propositional accounts claiming that EC and classical conditioning are both sensitive to the availability of attentional resources or contingency memory (e.g. Dawson & Furedy, 1976; De Houwer, 2007; Mitchell, De Houwer, & Lovibond, 2009). Admittedly, due to its relationship to auditory memory processes, the working memory effect on conditioning still appears to be confined to stimuli that can be encoded phonologically, i.e. to a verbal conditioning paradigm (as in C. K. Staats & Staats, 1957; A. W. Staats & Staats, 1958). Since there are studies, however, demonstrating disruption of visual or spatial short-term memory performance by irrelevant visual stimuli (i.e. the 'irrelevant pictures' effect, see H. D. Zimmer & Speiser, 2002), future research might be able to find analogous effects of visual working memory distraction in the picture-picture paradigm of EC (Levey & Martin, 1975).

Auditory distraction further impaired contingency knowledge. Stimulus pairings presented during phonological distraction (irrelevant speech or articulatory suppression) were recognized to a lesser extent in a final test than those pairs that were presented in silence, or together with white noise or FM tones. In addition to attentional distraction (Hammerl & Grabitz, 2000; Fulcher & Hammerl, 2001b; Field & Moore, 2005; Pleyers et al., 2009) and subliminal presentations of USs (e.g. De Houwer et al., 1994, 1997; Field & Moore, 2005), working memory disruptions represents yet another way to modulate contingency knowledge. Rather than generally diverting the subjects' attention by engaging them in secondary tasks, this method has the advantage of being suited to manipulate awareness on an item-by-item basis within subjects. There are different possible explanations as to how phonological distraction might affect contingency knowledge in a conditioning paradigm. Whereas the 'phonological loop' account predicts working memory disturbance depending on how speech-like the distracting sound is, the O-OER model refers to the amount of 'changing state' information provided by a particular sound. The results of experiment 3 are rather in line with the predictions of the phonological loop model because the small magnitude of disruption produced by FM tones is comparable to that produced by noise rather than by irrelevant speech. In addition, articulatory suppression consistently produced greater impairment of contingency knowledge than did irrelevant speech. Thus, the data of experiments 1 and 2 are in favor of the phonological loop model as well to account for the effect of working memory disturbance in an associative learning task.

In contrast to other studies, we did not find a clear relationship between contingency knowledge and EC. Though both EC and contingency memory were diminished with increasing phonological distraction, the EC effect was not restricted to those CS-US pairings that were finally recognized. At this point, the data seem to deviate from earlier findings that EC only emerges for those CS-US pairs that a participant is aware of (e.g. Pleyers et al., 2007, 2009; Stahl & Unkelbach, 2009). However, the present finding is in line with several other studies showing EC in the absence of contingency awareness (Baeyens et al., 1990; Dickinson & Brown, 2007; Field & Moore, 2005; Fulcher & Hammerl, 2001b; Hammerl & Grabitz, 2000; Hammerl & Fulcher, 2005; Walther & Nagengast, 2006). One might argue that the post-acquisition recognition measure was just not sensitive enough to detect the modulations of contingency knowledge that were produced by phonological disruption during the acquisition. Subjects' contingency knowledge in the acquisition phase might deviate from that measured in the final recognition test. The present data, however, suggest that memory at the time of acquisition (i.e. working memory), rather than post-acquisition contingency knowledge is crucial for EC to occur. Such a discrepancy between working memory during conditioning and contingency memory after conditioning could offer an explanation for the inconsistent results obtained with respect to the role of contingency awareness (e.g. Fulcher & Hammerl, 2001b; Pleyers et al., 2007). The present results indicate that EC depends on the availability of working memory resources during but not necessarily on a resulting (long-term) memory of the contingencies. In other words, the (temporary) processing of the CS-US pairings in working memory but not a transfer into long-term memory seem to be crucial for the acquisition of EC.

To sum up, the present study showed phonological disruption (i.e. articulatory suppression and the irrelevant speech effect) to be a useful method for studying the role of working memory in EC. In contrast to earlier studies (e.g. using attention-diverting secondary tasks), cognitive resources were manipulated within the same subject. The method thus appears suitable to elicit different degrees of contingency memory within subjects, and is presumably less transparent to participants than other manipulations that, for instance, explicitly redirect attention. The results suggest that EC occurs independently of contingency knowledge in terms of the resulting pair-recognition memory. Working memory resources available during conditioning, however, reliably affected the acquisition of EC. Both the production and the processing of irrelevant speech but not concurrently presented non-speech sounds (like FM tones) significantly impaired the acquisition of new evaluative responses. In other words, irrelevant speech interferes with evaluative learning.

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7. Manuscript C

Kattner, F. & Ellermeier, W. (in press). Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning. *Experimental Psychology*. doi: 10.1027/1618-3169/a000108. [1]

Abstract

An experiment is reported studying the impact of objective contingency and contingency judgments on cross-modal evaluative conditioning. Both contingency judgments and evaluative responses were measured after a contingency learning task in which previously neutral sounds served as either weak or strong predictors of affective pictures. Experimental manipulations of contingency and US density were shown to affect contingency judgments. Stronger contingencies were perceived with high contingency and with low US density. The contingency learning task also produced a reliable evaluative conditioning effect. The magnitude of this effect was influenced by an interaction of statistical contingency and US density. Furthermore, the magnitude of evaluative conditioning was correlated with the subjective contingency judgments. Taken together, the results imply that propositional knowledge about the CS-US relationship, as reflected in contingency judgments, moderates evaluative learning. The data are discussed with respect to different accounts of evaluative conditioning.

Keywords: evaluative conditioning, contingency learning, outcome density effect, US density, contingency judgments, contingency awareness, associative learning, propositional learning

[1]This manuscript may not exactly replicate the final version of the article published in *Experimental Psychology*. It is not the version of record and is therefore not suitable for citation.

7.1. Does evaluative learning rely on the perception of contingency? Manipulating contingency and US density during evaluative conditioning

Evaluative conditioning (EC) refers to an increase or decrease in the liking of a stimulus (the conditioned stimulus, CS) that results from pairing it with a positive or negative stimulus (the unconditioned stimulus, US), respectively (e.g. De Houwer, Thomas, & Baeyens, 2001). EC can thus be accounted as a form of Pavlovian conditioning affecting evaluative responses rather than overt behavior or physiological responses, and it is considered to be an important mechanism to account for the acquisition and change of preferences (De Houwer, 2007). In a prototypical experiment, CSs are being evaluated with respect to subjective liking before and after conditioning (Levey & Martin, 1975; Baeyens, Eelen, & Van den Bergh, 1990).

In contrast to classical Pavlovian conditioning (e.g. Rescorla, 1968), however, EC appears to be insensitive to modulations of the statistical contingency between the CS and the US, and it has been shown to occur even in the absence of contingency (Baeyens, Hermans, & Eelen, 1993). A recent meta-analysis reported no effect of additional CS-only or US-only trials (which are reducing contingency) on EC and no difference in the effect sizes of EC between perfect and partial contingency (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). This is in line with dual-process accounts suggesting that only expectancy learning requires the CS to statistically predict the US, whereas EC relies on a mere referential, simple Hebbian learning system where spatial or temporal contiguity between the CS and the US should be sufficient (e.g. Baeyens, Eelen, Crombez, & Van den Bergh, 1992; Baeyens, Vansteenwegen, Hermans, & Eelen, 2001). However, evidence for EC to occur independently of the CS-US contingency is extremely limited, yet (Hofmann et al., 2010).

Furthermore, there is an ongoing debate on whether EC requires the subject's awareness of the CS-US relationship. Accounts of EC differ with respect to the assumed role of contingency awareness (e.g. Baeyens et al., 1992; De Houwer, 2007), and the empirical results thereon are rather ambiguous. Whereas some studies found EC to occur independently of (Baeyens, Eelen, & Van den Bergh, 1990) and even in the absence of contingency awareness (e.g. Dickinson & Brown, 2007; Fulcher

& Hammerl, 2001; Hammerl & Fulcher, 2005), others found EC to be restricted to contingency-aware participants and to pairings that the participant is aware of (e.g. Dawson, Rissling, Schell, & Wilcox, 2007; Pleyers, Corneille, Luminet, & Yzerbyt, 2007; Pleyers, Corneille, Yzerbyt, & Luminet, 2009; Stahl & Unkelbach, 2009; Stahl, Unkelbach, & Corneille, 2009; Wardle, Mitchell, & Lovibond, 2007). Though a recent meta-analysis reported contingency awareness to be the most potent moderator variable in EC (it increases with contingency awareness), small but reliable EC effects have also been identified in the absence of contingency awareness (Hofmann et al., 2010).

There has been a great deal of criticism concerning the reliability and sensitivity of measures of contingency awareness going beyond the scope of this discussion (see Shanks & St. John, 1994; Field, 2000; Lovibond & Shanks, 2002). Typically, contingency awareness is measured by means of a forced-choice recognition test after conditioning asking the participant to identify the respective US (or its valence) that had been paired with a particular CS (Baeyens, Eelen, & Van den Bergh, 1990; Walther & Nagengast, 2006; Stahl et al., 2009). Thus, contingency awareness refers to the subject's knowledge about the fact that CS and US have been paired (i.e. contiguity) rather than to the subject's idea of how reliably the CS predicts the US (contingency).

By contrast, participants in a contingency learning task judge either the strength or the likelihood of the relationship between a potential cue (or response) and an outcome after having received some information about the co-occurrences of the cue and the outcome (e.g. Allan & Jenkins, 1983; Anderson & Sheu, 1995; Dickinson, Shanks, & Evenden, 1984). This information is provided by the frequencies of the four events defined by the presence or absence of the cue and the outcome (see table 7.1).

A common objective measure of statistical contingency is ΔP which refers to the difference between the conditional probability of the outcome given the cue and the conditional probability of the outcome in the absence of the cue (equation 7.1; see Allan, 1980).

$$\Delta P = \frac{a}{a+b} - \frac{c}{c+d} \tag{7.1}$$

Though different accounts of EC differ in terms of their predictions about the role of both objective contingency and contingency awareness, most of them are relatively

Table 7.1.: A 2 × 2 matrix representing the four types of events in contingency learning (corresponding events in a conditioning setting are written in parentheses). The frequencies of the four possible combinations are represented by the letters a, b, c, and d.

	Outcome present (US)	Outcome absent ($\neg US$)
Cue present (CS)	a (contiguity)	b (CS-only)
Cue absent ($\neg CS$)	c (US-only)	d

mute with respect to the appraisal of CS-US contingency (contingency judgments). Association-formation models assume EC to be affected mainly by the number of CS-US pairings rather than by CS-US contingency (e.g. Walther, 2002). According to the referential account (Baeyens et al., 1992), for instance, EC is supposed to rely on automatic processes which should not depend on awareness at all, whether it refers to stimulus contiguity or contingency (similar predictions are made by the holistic account Martin & Levey, 1978). Others assume EC to be a function of either the salience of the CS (implicit misattribution account; Jones, Fazio, & Olson, 2009) or that of features shared by the CS and the US (concept categorization account; Davey, 1994a) which is supposed to be moderated by awareness of the stimuli. There is, however, no reason to assume that awareness of contingencies should make those features more salient than awareness of contiguities. Finally, according to the propositional account, EC is expected to require awareness of the CS-US relationship (De Houwer, Baeyens, & Field, 2005; De Houwer, 2007, 2009; Mitchell, De Houwer, & Lovibond, 2009). Strictly spoken, learning should result from the formation and evaluation of propositional knowledge about the contingencies. EC is thus expected to vary with any variable that fosters the acquisition of contingency knowledge, e.g. objective contingency. Therefore, this model seems to be incompatible with the finding of EC to occur independently of contingency (e.g. Baeyens et al., 1993). However, it is possible that EC sometimes results from propositions about the co-occurrences of the CS and the US (contiguity knowledge) and does not necessarily require propositional knowledge about the contingency (Hofmann et al., 2010). In order to test whether EC is sensitive to the appraisal of statistical contingency, the present study intends to actively manipulate the subjects' conscious beliefs (i.e. their contingency judgments).

For this purpose, it is intended to manipulate contingency judgments independently of ΔP. Under optimal conditions subjects' propositional knowledge should reflect ΔP quite well (De Houwer, 2007; Shanks, 1995). However, contingency judgments are known to be influenced by a number of factors irrelevant to contingency, as well (Allan, 1993; Shanks, 1995). Particularly, stronger contingency relationships are perceived with shorter gaps between the cause and the outcome (Shanks, Pearson, & Dickinson, 1989) and with longer inter-trial intervals (Msetfi, Murphy, Simpson, & Kornbrot, 2005; Msetfi, Murphy, & Simpson, 2007). Further, contingency judgments reflect the density of outcomes (i.e. the number of outcome trials divided by the total number of trials). With a few exceptions (e.g. Wasserman, Elek, Chatlosh, & Baker, 1993), contingency judgments tend to increase with outcome density independently of ΔP (e.g. Alloy & Abramson, 1979; Allan & Jenkins, 1983; Allan, Siegel, & Hannah, 2007; Dickinson et al., 1984; Vallée-Tourangeau, Murphy, & Baker, 2005). Recently, the use of signal-detection theory on contingency learning demonstrated that outcome density has an effect on the response tendency (i.e. the probability of 'strong-contingency' responses) rather than on the ability to judge the contingency relationship (Allan, Siegel, & Tangen, 2005; Allan, Hannah, Crump, & Siegel, 2008). Subjects reported stronger contingencies in case of high outcome density, but the slopes of the psychometric functions remained unaffected. The point of subjective equality (the objective contingency at which subjects report strong and weak contingencies equally often) was about .05 lower on the ΔP-scale when outcome density was .7 than when it was .3 (at least in the psychometric functions of 3 of 4 participants, see figure 8 in Allan et al., 2008). Thus the response tendency rather than the sensitivity to contingency information seems to increase with outcome density. Nevertheless, since both the response bias and the sensitivity are supposed to influence the contingency appraisal, outcome density modulations appear to be a useful approach to manipulate the propositional knowledge about contingencies during EC.

The present study intends to show cross-modal EC with environmental sounds as CSs and pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) as USs in a paradigm that simultaneously requires the subject to judge the CS-US contingencies. In order to manipulate the perceived contingency independently of ΔP, the density of US trials was varied. With constant ΔP, subjects are supposed to perceive a stronger contingency when US density increases. Additionally, contingency judgments are expected to reflect objective contingency.

If EC results from the same processes that are involved in expectancy learning (e.g. Rescorla, 1988), then the magnitude of EC should be a function of ΔP. By contrast, if merely referential processes cause EC, then only contiguity (which was held constant in the present study) but neither the contingency nor subjective beliefs (modulated by US density) are expected to affect EC (e.g. Baeyens et al., 1992). According to the propositional account, EC should basically depend on the acquired knowledge concerning the CS-US relationship, rather than on objective values of contingency (De Houwer, 2007). EC is assumed to occur only in contingency-aware subjects, and its magnitude is expected to reflect the knowledge about either the co-occurrences (i.e. the level of contingency awareness) or the statistical contingency (i.e. contingency judgments). If EC is sensitive to the appraisal of contingency, then it should be affected by manipulations of both US density and ΔP because both are expected to affect the contingency judgment.

7.2. Method

7.2.1. Participants

31 (14 female) participants with a median age of 21 years (ranging from 19 to 26) were recruited at the campus of Technische Universität Darmstadt. The majority of them were undergraduate students not majoring in psychology. They participated in individual experimental sessions of about 45 minutes and were compensated with €8.

7.2.2. Materials and apparatus

CSs were selected according to individual pleasure ratings from a set of 32 short natural monophonically recorded sounds, depicting a great variety of acoustical events like animal voices (e.g. of birds, bees, or a horse), human body noises (e.g. a laugh or a clap), musical instruments (e.g. a cymbal or a fanfare horn), video-game-type sounds or other noises (e.g. a hammer or water). Sounds were played back at equal RMS levels (63 dB SPL) and the duration varied between 200 and 350 ms. Eight IAPS pictures (Lang et al., 2008) with positive (nos. 4220, 7580, 7480, 8200) or negative (nos. 1111, 3064, 9410, 9571) valence served as liked and disliked USs, respectively.

The experiment was run in a single-walled sound-attenuated listening room (IAC). Visual stimuli were displayed on a 19" TFT monitor (Philips) and the sounds were presented via headphones (Beyerdynamics DT-990). Stimulus presentations and response measurements were controlled by a Matlab program, using the Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997).

7.2.3. Experimental design

The standard EC paradigm was modified in order to allow simultaneous CS-US contingency learning. In contrast to contingency learning which is basically a matter of only two events (the cue and the outcome), multiple cues and outcomes (i.e. CSs and USs) were presented in a differential conditioning procedure. Since there is no easy way with multiple contingencies to assign a no-event (d in table 6.1) to a particular CS-US pairing without introducing additional context cues, the frequency of the absence of both CS_i and US_i was defined as the total number trials within the conditioning block (n) less those involving CS_i or US_i. Thus contingency and US density of $CS_i - US_i$ were defined according to equations 7.2 and 7.3, respectively.

$$\Delta P_{CS_i US_i} = \frac{a_i}{a_i + b_i} - \frac{c_i}{n - a_i - b_i} \tag{7.2}$$

$$P(US_i) = \frac{a_i + c_i}{n} \tag{7.3}$$

A $2 \times 2 \times 2$ design was implemented with US valence, contingency and US density as independent variables. Two learning blocks were created that differed in the level of contingency. US density and US valence varied between the four stimulus pairings presented within a block (compare table 7.2). Dependent measures were contingency recognition, contingency judgments and evaluative responses.

7.2.4. Procedure

In the baseline phase, the 32 sounds were rated on a 21-category scale (ranging from -10 to $+10$) with respect to subjective liking or disliking. Based on these ratings, those eight sounds rated closest to zero were selected to be used as CSs in the subsequent phases. Eight CS-US pairings were created by randomly assigning

Table 7.2.: The values of b, c and d in the contingency matrix for the eight CS-US pairings and the resulting values of ΔP, US density and CS density within the two learning blocks.

Block	b	c	d	ΔP	US density	CS density	US valence
1	8	3	94	low (.50)	low (.11)	.15	positive
	8	3	94	low (.50)	low (.11)	.15	negative
	3	25	77	low (.50)	high (.30)	.11	positive
	3	25	77	low (.50)	high (.30)	.11	negative
2	3	0	62	high (.75)	low (.12)	.16	positive
	3	0	62	high (.75)	low (.12)	.16	negative
	0	16	49	high (.75)	high (.34)	.12	positive
	0	16	49	high (.75)	high (.34)	.12	negative

Note: b = number of CS-only trial ; c = number of US-only trial; d = number of trial belonging to a different pairing in the same block; a (the number of CS-US trials) was 9 in all conditions. The total number of trials was 114 in block 1, 74 in block 2

each neutral sound to either a positive or negative US (picture). The main part of the experiment consisted of two separated learning blocks. The task required the subject to simultaneously learn the contingency of four CS-US pairings. In each block, two pairs with a positive US and two pairs with a negative US were presented nine times each in a randomized order. Statistical contingency was low ($\Delta P = .5$) in block 1 and high ($\Delta P = .75$) in block 2, and it was held constant across the four stimulus pairs within a block. The order of the blocks was counterbalanced across participants. US density varied within the blocks: Two USs were presented with high density (in 10% of the trials each), and two USs were presented with low density (in 30% of the trials each). Note that no US was presented in the remaining 20% of trials. In order to modulate contingency and US density, the values of b and c in the contingency matrix were varied (see table 6.2 for the exact frequencies). Since the frequency of d was derived from those trials belonging to a different pairing (see above), there were no trials without any stimulus. A variable trace conditioning procedure was used in which the US was always displayed 0.5 s after the onset of the CS. The US was displayed for 0.5 s and the inter-trial interval was 1 s. Prior to the first learning block, participants were given the following instruction (translated from German):

> Welcome to our study!
> We are interested in how good people are in learning that sounds predict certain events. We first ask you rate each stimulus spontaneously according to how pleasant or unpleasant it sounds by means of a scale that will appear on the screen. The scale ranges from -10 (very unpleasant) through 0 (neutral) to +10 (very pleasant). Then, several noises and pictures will appear repeatedly. Particular noises will always predict certain pictures more or less reliably. You will observe several instances of four different events:
> (1) the sound is presented prior to the picture
> (2) the sound is presented without the picture
> (3) the picture appears without the sound
> (4) neither the [particular] sound nor the [particular] picture appears
> Your task is to figure out how reliably each picture can be predicted by a particular sound. After a couple of trials, we will ask you to identify each sound-picture pairing and to judge the strength of its relationship by means of a rating scale ranging from 0 (no contingency) to 100 (strong contingency). A strong contingency means that most of the time you hear the sound you also see the picture, and most of the time you don't hear the sound you also do not see the picture. A weak contingency means that the picture appears in the presence of the sound as often as it appears in the absence of the sound.
> Do you have any questions?

After each block, evaluative responses, contingency awareness, and contingency judgments were measured with respect to the stimuli presented in the block. Short additional instructions were given prior to each task. First, the pleasantness of each sound was rated on the same 21-category scale as used in the baseline rating phase (evaluative response). Second, the subject had to select the picture which had been paired with the particular sound among all four pictures that were presented in the block (contingency awareness). Similar to the procedure developed by Baeyens, Eelen, and Van den Bergh (1990), a subject was classified as aware of a pairing if either the correct picture (the US) or a different picture of the same valence as the US was selected (q.v. Davey, 1994b). Third, participants were asked to judge the contingency between the sound and the picture by means of a 21-category scale ranging from 0 (no contingency) to 100 (perfect contingency).

7.3. Results

For all statistical tests, a p-value of less than .05 was accepted as significant.

7.3.1. Contingency awareness

The participants correctly recognized 94.4% of the CS-US pairings. A different picture with the same valence as the US was selected in additional 3.1% of the cases. Thus, subjects were clearly unaware only with respect to 2.5% of the pairings. Due to the low percentage of unawareness, the data were collapsed across contingency-aware and contingency-unaware items for the analysis of contingency judgments.

7.3.2. Contingency judgments

Figure 7.1 illustrates the contingency judgments of CS-US pairings with positive and negative USs as a function of ΔP and US density. The mean CS-US contingency judgment was 50.2 ($SD = 29.1$) in the low-contingency block and 61.1 ($SD = 28.5$) in the high-contingency block. On average, the contingency of pairings with low and high US density was judged 59.4 ($SD = 29.3$) and 51.8 ($SD = 28.8$), respectively. A 2 (US density) $\times$ 2 (contingency) $\times$ 2 (US valence) repeated-measures ANOVA on the contingency judgments revealed two significant main effects, one for contingency, $F(1, 30) = 11.22; p < .01$, and one for US density, $P(1, 30) = 4.46; p < .05$. There was no main effect of US valence, $F(1, 30) = 1.90; p = .18$, and there were no significant interactions, all $Fs < 1$.

To get an idea of whether the effects of US density on the contingency judgments reflect changes in the sensitivity to contingency information or a shift in the response

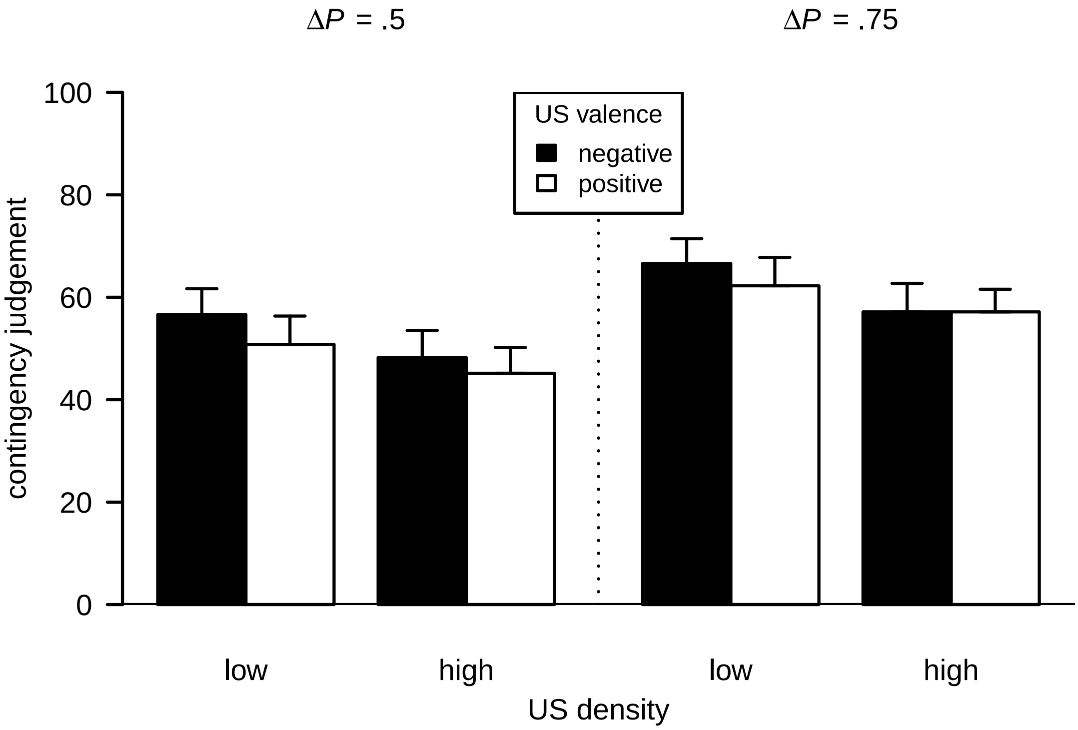

Figure 7.1.: Contingency judgments of CS-US pairings as a function of US density and contingency.

criterion, the pooled data were further analyzed by treating them according to the rating paradigm in a signal-detection experiment (Macmillan & Creelman, 1991). High-contingency pairings ($\Delta P = .75$) served as signal trials and low-contingency pairings ($\Delta P = .5$) served as noise trials. The sensitivity to contingency information (d') and the response criterion (c) were computed for each category on the contingency rating scale[2] from the z-scores of the probabilities of hits and false alarms according to equation 7.4 and 7.5 (see Allan et al., 2005, for some details).

$$d' = \frac{\mu_{.75} - \mu_{.5}}{\sigma} = z(yes|\Delta P = .75) - z(yes|\Delta P = .5) \tag{7.4}$$

[2]Contingency judgments can be interpreted as confidence ratings for perceiving high contingency (greater contingency judgments indicate a higher certainty that the pairing has been presented with high contingency). In order to compute hit rates and false alarm rates, the ratings were grouped into categories (0-15, 20-35, 40-55, 60-75, 80-100). Any response falling into a given category or a higher (stricter) one was defined as a *yes* response (meaning 'high contingency') and any response in a less strict category was defined as a *no* response ('low contingency'). A hit was defined as a *yes*-response to a high-contingency pairing and a false alarm was defined as a *yes*-response to a low-contingency pairing.

$$c = \frac{z(yes|\Delta P = .75) + z(yes|\Delta P = .5)}{-2} \tag{7.5}$$

Across categories, the analysis revealed a mean sensitivity of $d' = 0.37$ for pairings with low US density and $d' = 0.43$ for those with high US density. The response criteria are shown in table 7.3. Responses were consistently more liberal for low US density pairings ($c = -0.40$) than for high US density pairings ($c = -0.12$).

Table 7.3.: Response criteria c for four arbitrary category boundaries along the (0-100) contingency rating scale.

yes-response	low US density	high US density
≥ 20	-1.26	-0.98
≥ 40	-0.65	-0.47
≥ 60	-0.15	0.12
≥ 80	0.44	0.84

7.3.3. Evaluative Ratings

Mean evaluative ratings of CSs before and after conditioning are depicted in figure 7.2. Evaluative rating differences were computed by subtracting the evaluative ratings in the baseline phase from those obtained after the respective contingency learning block. The grand mean of the evaluative rating shifts for sounds that were paired with positive or negative pictures was $0.57 (SD = 3.61)$ and $-1.64 (SD = 3.63)$, respectively.

A 2 (US density) $\times$ 2 (contingency) $\times$ 2 (US valence) ANOVA confirmed the overall EC effect by revealing a significant main effect of US valence on the evaluative rating differences, $F(1, 30) = 11.62; p < .01$. Furthermore, there was a significant three-way interaction between US valence, contingency and US density, $F(1, 30) = 6.41; p < .05$, implying that the effects of US density on EC differ between conditions with low and high contingency (see figure 7.2). The ANOVA revealed no main effects of contingency and US density, and no significant two-way interaction, all $Fs < 1$. Additional two-way ANOVAs revealed a marginally significant US valence $\times$ US density interaction in the low-contingency block, $F(1, 30) = 3.34; p = .08$, but not in the high-contingency block, $F(1, 30) = 1.92; p = .18$. There were significant main

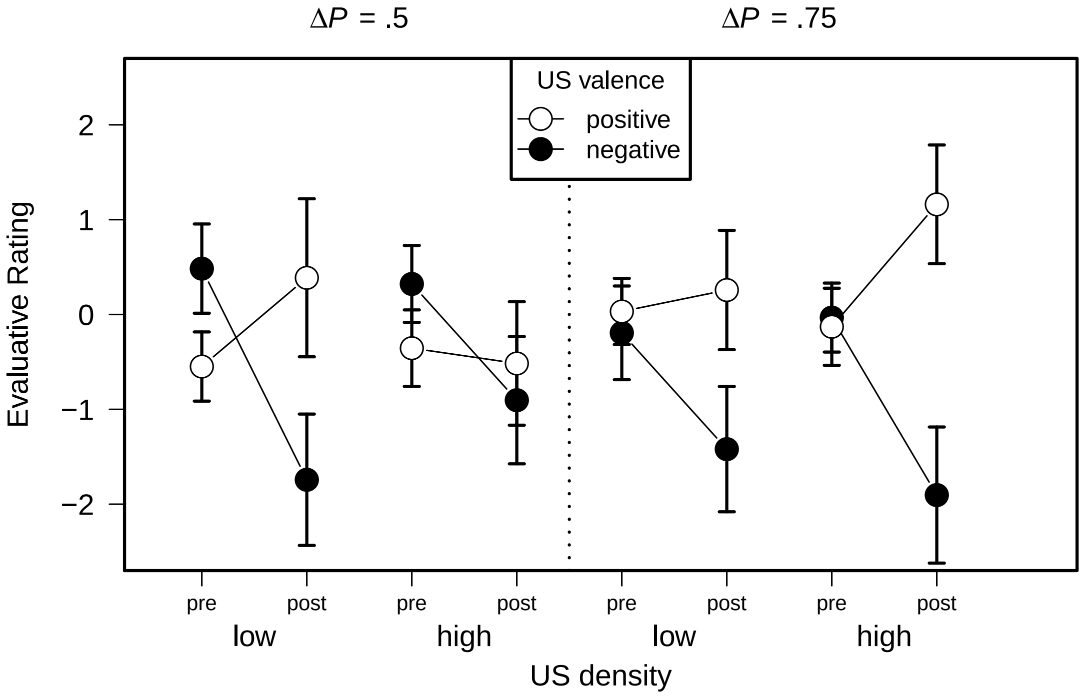

Figure 7.2.: Evaluative ratings in the baseline phase (pre) and after conditioning (post) as a function of US density and contingency.

effects of US valence in both blocks, $F(1,30) = 8.70; p < .01$ and $F(1,30) = 6.78; p < .05$, respectively.

7.3.4. Relation between contingency judgments and EC

The absolute value of the EC effect was computed individually for each stimulus pair and participant by multiplying the evaluative rating difference with the respective valence index (-1 for negative USs, $+1$ for positive USs). The eight correlations between the contingency judgments and the EC scores computed for each US valence $\times$ contingency $\times$ US density condition were significantly greater than zero, $\bar{r} = .15; t(7) = 2.03; p < .05$. Since correlations computed across subjects might reflect effects of individual response biases (e.g. a proclivity towards high contingency judgments going along with a tendency to assign extreme evaluative ratings), additional correlations were computed for each subject, where between-subjects differences cannot contribute to generating spurious effects. These correlations between EC and contingency judgments were also significantly different from zero, $\bar{r} = .16; t(30) = 2.16; p < .05$.

In order to compare the magnitude of EC for low and high perceived contingencies, the data were split along the median of the contingency judgments (60). The EC effect was found to be significantly greater in the upper half of the perceived-contingency continuum ($M_{EC} = 1.62; SD = 4.02$) compared to its lower half ($M_{EC} = 0.58; SD = 3.17$), $t(123) = 2.50; p < .05$.

7.4. Discussion

The aim of the reported experiment was to show whether EC depends on objective contingency and/or propositional knowledge about contingencies which was manipulated via US density. The modified conditioning paradigm produced an overall effect of EC: The liking of sounds that were paired with positive pictures increased and the liking sounds that were paired with negative pictures decreased.

Formerly, EC has been demonstrated within a variety of stimulus modalities, including verbal (Staats & Staats, 1957), visual (Hammerl & Grabitz, 1993), haptic (Hammerl & Grabitz, 2000), or flavor stimuli (Baeyens, Eelen, Van den Bergh, & Crombez, 1990). The auditory modality, however, has been neglected so far. Though a few studies found cross-modal EC with music as the US (e.g. Eifert, Craill, Carey, & O'Connor, 1988), the authors are not aware of any study demonstrating changes in the liking of auditory CSs. The present results thus show that, in addition to the visual, haptic, or flavor perception of the CS, EC can also be demonstrated quite reliably with auditory CSs. Furthermore, the data lend evidence to cross-modal EC. The conceptual categorization account, for instance, assumes EC to result from perceiving common features in the CS and the US which become salient during conditioning and should thus diminish when using different stimulus modalities (Davey, 1994a; Field & Davey, 1999). Similarly, according to the implicit misattribution account, dissimilar CSs and USs should make an affective transfer unlikely (Jones et al., 2009). The robustness of the affective transfers in the present cross-modal setting within and across learning blocks challenges both accounts, and is in line with Hofmann et al.'s (2010) conclusion that EC is independent of whether CS and US match in terms of stimulus modality.

Due to the instructions to learn the contingencies, subjects were aware of the great majority of stimulus pairings, and the study thus replicates the occurrence of EC in contingency-aware subjects (e.g. Dawson et al., 2007; Pleyers et al., 2007; Stahl et al., 2009). Since subjects were unaware only with respect to a few stimulus pairings, the data cannot tell us anything about unaware EC, but they are inconsistent with the occasionally reported finding that explicitly inducing contingency awareness eliminates (or reverses) EC (Fulcher & Hammerl, 2001; Hammerl & Fulcher, 2005). In aware participants, however, the appraisal of the contingency might vary between the different conditioning procedures used - maybe due to the specific instructions - and partially account for the divergent results obtained in previous studies.

The subjective appraisal of contingency was the main focus in the present study. As expected, contingency judgments varied as a function of ΔP. CS-US contingency was clearly judged higher (about 11% on the contingency scale) in the high-contingency block compared to the low-contingency block. Thus, participants learned to discriminate the contingencies with four contingency relations being judged simultaneously within the same learning block (the effects were only slightly smaller compared to other studies, e.g. Allan et al., 2007, figure 1, for an instance with the same values of ΔP). It is obvious that this makes contingency ratings more complex than a task with only one cue and one outcome. Nevertheless, though subjects were clearly sensitive to variations in ΔP, the contingency judgments also varied with the density of US presentations. Greater contingency was perceived when the USs occurred with low density than when they occurred with high density (about 7.5% difference on the contingency scale). This effect is rather unusual for both cue-outcome and action-outcome contingency learning tasks where higher outcome density is typically accompanied with higher contingency judgments (compare e.g. Allan, 1993; Alloy & Abramson, 1979; Dickinson et al., 1984). In the present multiple-contingency learning task, high US density was achieved by dramatically increasing the number of US-only trials, and by slightly decreasing the number of CS-only trials (compare table 7.2; the indirect modulations in the frequency of *d*-trials are supposed to be less salient). Thus, subjects might particularly have noticed the great number of US-only trials in high US-density pairings, and have underestimated the contingency due to the fact that those salient US-only trials, according to the instructions, indicate low contingency. However, similar reversed outcome density effects were found in the action-outcome tasks used by Wasserman, Chatlosh, and Neunaber (1983) and Wasserman et al. (1993). For several instances of ΔP, the authors reported less extreme (positive and negative) contingency judgments with increasing outcome density. Vallée-Tourangeau et al. (2005), however, failed to replicate this effect when the confounded time lag between the response and the outcome (temporal contiguity) was held constant. Since temporal contiguity (the SOA between the sound and the picture) varied only with CS duration and was not confounded with US density in the present study, the effect might be more than an artifact in contingency learning[3].

Signal detection analyses demonstrate that US density manipulations primarily affected the response bias. Particularly, there was a tendency to make more 'high contingency' judgments with low US density, whereas the sensitivity to contingency information did not vary considerably with US density. Though the density effect itself was reversed, the present data thus replicate the finding that outcome density modulations lead to changes in response bias rather than in the ability to perceive contingency (Allan et al., 2005, 2008). Nevertheless, US density did affect contingency judgments and is assumed to have successfully altered the participants' propositional knowledge about the CS-US relationship.

The evaluative rating differences were affected by US valence (EC effect) and by a three-way interaction of valence, contingency, and US density. This indicates that the impact of US density on EC depends on the level of contingency: Whereas the magnitude of EC was insensitive to (or tended to increase with) US density in the high-contingency block, it decreased with US density in the low-contingency block. According to the referential and the holistic account (Baeyens et al., 1992; Martin & Levey, 1978), EC should neither depend on contingency nor on US density but only on the number of CS-US pairings. The present data are at odds with these predictions because - with constant contiguity - EC was modulated by an interplay of US density and contingency. By contrast, if EC relies on the same processes that are involved in Pavlovian signal learning, then the magnitude of EC should be a function of objective contingency. However, this was not the case in the present study, either, because reliable effects of EC were observed for $\Delta P = .5$ and for $\Delta P = .75$. Thus, the present data support the assumption that EC is not sensitive to modulations of the statistical CS-US contingency (Baeyens et al., 1993). Admittedly, an

[3]A similar pattern of density effects has also been reported in autonomic conditioning where the magnitude of conditioned skin conductance responses increased when the density of reinforcements was reduced by either varying the number of reinforced trials or the inter-trial interval (Lachnit, Lober, Reinhard, & Giurfa, 2002; Lachnit, Ludwig, & Reinhard, 2007).

increase of the CS-US contingency was accompanied with greater EC effects if the USs occurred frequently, and the EC effect tended to decrease with contingency if US density was low. According to the propositional account of EC (e.g. De Houwer et al., 2005; De Houwer, 2007), both contingency and US density should have an effect on conditioning because both are expected to modulate the crucial propositional knowledge about the contingency relationship between the CS and the US. The finding that EC was affected by an interaction of US density and contingency might thus be accounted best by looking at the produced contingency judgments. Indeed, both the magnitude of EC and contingency judgments were lowest in the condition with low contingency and high US density (particularly, in this condition the evaluative ratings of CSs that were paired with positive USs decreased), whereas more pronounced EC effects and greater contingency ratings were observed in the remaining conditions. This pattern of results indicates that EC is sensitive to contingency judgments rather than to the objective level of contingency and it is compatible with the propositional account of EC.

In line with this conclusion, the magnitude of EC was found to be positively correlated with contingency judgments: Both types of correlations - within and between subjects - revealed that stronger perceived contingencies go along with greater evaluative learning effects. Admittedly, the correlation does not imply causality, but - if anything - it appears more plausible that the perception of a high contingency produces stronger evaluative shifts than the other way around. Thus, in addition to the observed correlation between EC and contingency awareness (e.g. Stahl et al., 2009), the present results show that there is also a connection between more qualified propositions about the stimulus relation and the magnitude of EC. Particularly, the appraisal of strong contingency appears to foster EC in subjects who acquired knowledge about the contiguities.

To sum up, EC was influenced by an interplay of US density and ΔP both of which were shown to affect the contingency judgments. Furthermore, EC increased with contingency judgments, but not with objective contingency. To some extent, this is in contradiction with dual-process accounts assuming a separate referential learning system to be responsible for EC (e.g. Baeyens et al., 1992). Instead, the results imply that propositional knowledge about the CS-US contingency moderates the acquisition of EC, thus supporting the propositional account (e.g. De Houwer, 2007). Once subjects acquired knowledge about the fact that the respective stimuli are being presented contiguously (contingency awareness), elaborated knowledge about the statistical relationship characterizing the co-occurrences of the CS and the US appears to further strengthen EC.

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Part III.

Appendix

A. Original instructions (German)

A.1. Instructions belonging to manuscript A

Instruction presented prior to the baseline rating phase

Herzlich Willkommen zu unserem Versuch! Vielen Dank, dass Sie sich bereit erklärt haben, daran teilzunehmen. Wir werden gleich einige Bildmotive und Szenarien zeigen, wie sie auch in vielen Werbe- anzeigen zu sehen sind. Bitte bewerten Sie jedes Bild möglichst spontan nach Ihrem subjektiven Empfinden. Achten Sie dazu besonders auf den ersten Eindruck, den das Bild bei Ihnen hinterlässt, sobald es erscheint. Unter jedem Bild werden Sie eine Skala sehen, die von -10 (gefällt mir nicht) bis +10 (gefällt mir sehr) reicht. Bitte wählen Sie jeweils einen Ihrem spontanen Empfinden entsprechenden Zahlenwert, indem Sie mit der linken Maus- taste darauf klicken. Wir bitten Sie außerdem, während der Durchführung des Versuchs nicht zu sprechen. Falls Sie noch Fragen haben, dann melden Sie sich bitte jetzt. Drücken Sie die Leertaste, um zu beginnen.

Instruction presented to the awareness-induction group prior to the acquisition phase

Um alltägliche Lebenssituationen zu simulieren (z.B. wenn Sie beim Einkaufen an diversen Werbeplakaten vorbeigehen), werden wir einige der Werbeanzeigen nun mehrmals praesentieren. Dabei werden immer jeweils zwei bestimmte Bilder kurz hintereinander zu sehen sein. Bitte versuchen Sie sich moeglichst viele dieser Paare zu merken. Am Ende des Versuchs werden diese in einem Test ab- gefragt werden. Melden Sie sich jetzt, falls Sie noch Fragen haben. Druecken Sie die Leertaste, um zu beginnen.

Instruction presented to the full-distraction group prior to the acquisition phase

Um alltaegliche Lebenssituationen zu simulieren (z.B. wenn Sie beim Einkaufen an diversen Werbeplakaten vorbeigehen), werden wir einige der Werbeanzeigen nun mehrmals praesentieren. Eine typische Aufgabe in solchen Situationen ist es, kleine Kopfrechnungen (z.B. Preise addieren) durchzufuehren. Sie werden darum neben den Bildern verschiedene Gleichungen sehen. Ihre Aufgabe ist es, fuer jede Gleichung zu entscheiden, ob sie wahr oder falsch ist. Druecken Sie bitte die 1 auf dem Ziffernblock, wenn die Rechnung falsch ist, und druecken Sie die 3, wenn die Gleichung wahr ist. Immer nach etwa acht Sekunden wird eine neue Aufgabe erscheinen. Sobald die neue Rechenaufgabe erscheint, loesen Sie bitte diese, auch wenn Sie mit der vorigen Aufgabe noch nicht fertig sind. Bitte loesen Sie die Aufgaben so schnell und korrekt wie moeglich. Nachdem Sie eine Taste gedrueckt haben, wird oben angezeigt, ob Ihre Antwort korrekt oder falsch war. Wenden Sie Ihren Blick bitte nie vom Bildschirm ab, damit Sie keine Aufgabe verpassen. Sehen Sie sich auch die Bilder an. Melden Sie sich jetzt, falls Sie noch Fragen haben. Druecken Sie die Leertaste, um zu beginnen.

Instruction presented to the contingency-distraction group prior to the acquisition phase

Um alltägliche Lebenssituationen zu simulieren (z.B. wenn Sie beim Einkaufen an diversen Werbeplakaten vorbeigehen), werden wir einige der Werbeanzeigen nun mehrmals präsentieren. Eine Gedaechtnisaufgabe in solchen Situationen koennte es sein, sich bestimmte Artikelnummern zu merken. In diesem Versuch ist darum jedem Bild eine bestimmte Ziffer (1, 2 oder 3) zugeordnet. Ihre Aufgabe ist es, die zu jeder Werbeanzeige gehörige Ziffer zu lernen. Bitte druecken Sie dazu, sobald ein Bild erscheint auf eine Taste auf dem Ziffern- block. Anfangs muessen Sie natuerlich einfach raten. Sie werden dann jeweils eine Rueckmeldung bekommen, die Ihnen sagt, ob dies die richtige Ziffer war. Jedes Bild wird immer nur kurz zu sehen sein. Druecken Sie darum moeglichst schnell eine Taste. Melden Sie sich jetzt, falls Sie noch Fragen haben. Druecken Sie die Leertaste, um zu beginnen.

Instruction presented prior to the test phase

Es ist durchaus möglich, dass sich Bewertungen verändern. Wir möchten Sie daher bitten, einige Bilder erneut zu bewerten. Geben Sie dazu bitte wieder Ihre spontane Bewertung ab, indem Sie auf einen Zahlenwert zwischen -10 (gefällt mir nicht) und +10 (gefällt mir sehr) klicken. Haben Sie noch Fragen? Weiter mit Leertaste.

Instruction presented prior to awareness assessment

In der folgenden Aufgabe werden Sie in unregelmäßigen Abständen hintereinander einige Bilder und Wörter auf dem Bildschirm sehen. Bei den Wörtern wird es sich um eindeutig positive oder negative Substantive handeln. Ihre Aufgabe ist es nun, das Wort jeweils so schnell und korrekt wie möglich als positiv oder negativ einzustufen. Verwenden Sie dazu bitte einfach die Maus: Drücken Sie die rechte Maustaste, wenn das Wort positiv ist und drücken Sie die linke Maustaste, wenn es negativ ist. Immer kurz vor einem Wort wird ein Bild er- scheinen. Dieses können Sie ignorieren, bewerten Sie diesmal bitte nur die Wörter. Legen Sie die Finger nun bitte jetzt bequem auf die beiden Maustasten. Melden Sie sich jetzt, falls Sie Fragen haben. Drücken Sie die Leertaste, um zu beginnen.

A.2. Instructions belonging to manuscript B

Instruction presented prior to the baseline rating phase

Herzlich Willkommen zu unserem Versuch!
Phase 1: Namen bewerten

Vielen Dank, dass Sie sich bereit erklärt haben, daran teilzunehmen.
Wir suchen geeignete Namen für verschiedene gute und böse Charaktere einer neuen Comicserie. Darum möchten wir herausfinden, welche Namen eher angenehm, welche eher neutral und welche eher unangenehm klingen.
Im Folgenden werden Sie eine Reihe von möglichen Namen sehen. Ihre Aufgabe ist es, diese spontan nach Ihrem subjektiven Gefallen zu bewerten. Dazu wird jeweils eine Skala von -10 (sehr unangenehm) über 0 (neutral) bis +10 (sehr angenehm) angezeigt. Bitte stufen Sie jeden Namen ein, indem Sie mit der Maus auf ein Feld dieser Skala klicken. Denken Sie bitte nicht lange nach,sondern verlassen Sie sich auf Ihr unmittelbares Gefühl. Wenn Sie noch Fragen haben, wenden Sie sich bitte jetzt an die Versuchsleitung.

Drücken Sie eine beliebige Taste, um zu beginnen.

Instruction presented prior to the acquisition phase (experiments 1 and 2)

Phase 2: Vor- und Nachnamen lernen

Um herauszufinden, welche Kombinationen von Namen besonders gut im Gedächtnis bleiben, werden wir Ihnen im Folgenden die Vor- und Nachnamen

einiger Charaktere zusammen darbieten. Bitte versuchen Sie, sich diese Namenspaare so gut wie möglich zu merken. Sagen Sie sich die Namen dazu innerlich vor, damit Sie sich den Klang einprägen. Sprechen Sie die Namen aber bitte NICHT laut aus. Am Ende des Versuchs werden wir ab- fragen, an wieviele Paare Sie sich noch erinnern. Unmittelbar vor jedem Namenspaar wird eine kurze Mitteilung angezeigt. Wenn Sie dort die Anweisung "Sprechen Sie bitte" lesen, dann sprechen Sie bitte die Worte "drei-vier-fünf-drei-vier-fünf.." so lange langsam, laut und deutlich aus bis die nächste Mitteilung erscheint. Wenn Sie die Anweisung "Ruhe bitte" lesen, dann sprechen Sie bitte nicht. Hin und wieder werden Sie eine Stimme aus dem Kopfhörer hören. Diese können Sie einfach ignorieren. Konzentrieren Sie sich bitte darauf, die Namenspaare zu lernen und genau dann zu sprechen, wenn es verlangt wird. Wenn Sie noch Fragen haben, wenden Sie sich bitte jetzt an die Versuchsleitung.

Bitte setzen Sie nun die Kopfhörer auf und drücken Sie eine beliebige Taste, um zu beginnen.

Instruction presented prior to the acquisition phase (experiment 3)

Phase 2: Namenpaare lernen

Um herauszufinden, welche Namenskombinationen besonders gut im Gedächtnis bleiben, werden wir Ihnen im Folgenden jeweils zwei Namen kurz hintereinander darbieten. Bitte versuchen Sie, sich so viele dieser Namenpaare wie möglich zu merken. Sie können sich die Namen innerlich vorsagen, sprechen sie sie aber bitte nicht laut aus. Am Ende des Versuchs werden wir in einem Test abfragen, wieviele Paare sie noch erinnern. Während Sie die Namen sehen, werden Sie mehrere Hintergrundgeräusche hören. Dies soll eine typische Geräuschkulisse simulieren und die Aufgabe dadurch etwas erschweren. Sie können die Geräusche einfach ignorieren. Wenn Sie noch Fragen haben, wenden Sie sich bitte jetzt an den Versuchsleiter.

Bitte setzen Sie nun die Kopfhörer auf (Kabel links) und drücken Sie eine beliebige Taste, um zu beginnen.

Instruction presented prior to the test phase

Phase 3: Namen bewerten
-- Sie

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können die Kopfhörer nun wieder abnehmen. Wir möchten Sie jetzt bitten,
nochmals eine Reihe von Namen zu bewerten. Bitte stufen Sie diese wieder
spontan auf einer Skala von -10 (sehr unangenehm) über 0 (neutral) bis
+10 (sehr angenehm) ein. Denken Sie dabei bitte nicht lange nach, sondern
verlassen Sie sich wieder auf Ihr unmittelbares Gefühl. Wenn Sie noch
Fragen haben, wenden Sie sich bitte jetzt an die Versuchsleitung.
----------------------------------------------------------------------
Drücken Sie eine beliebige Taste, um zu beginnen.
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Instruction presented prior to the awareness assessment

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Phase 4: Wiedererkennungstest
-------------------------------------------------------------------------
Das Experiment ist nun fast zu Ende. Wir möchten nun testen, wie viele
Namenpaare Sie sich merken konnten. Dazu werden Sie im Folgenden auf dem
Bildschirm jeweils sechs Namenspaare sehen, von denen aber nur eines so
in der Lernaufgabe enthalten war. Bitte klicken Sie jeweils auf das Feld
neben dem korrekten Namenspaar. Bitte entscheiden Sie sich immer für ein
Paar, auch wenn Sie sich nicht sicher sind! Haben Sie noch Fragen?
-------------------------------------------------------------------------
Weiter mit beliebiger Taste.
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A.3. Instructions belonging to manuscript C

General instruction paper explaining the multiple-contingency learning task (given to the participants prior to the experiment)

Herzlich Willkommen zu unserem Versuch!

Wir interessieren uns dafuer, wie gut Menschen lernen koennen, dass einzelne Geräusche bestimmte Ereignisse ankuendigen.

Der Versuch besteht aus mehreren Phasen. Zunächst muessen Sie eine Reihe von Geräuschen moeglichst spontan danach beurteilen, wie angenehm bzw. unangenehm sie klingen. Wir bitten Sie, jedes Geräusch auf einer Skala von -10 (sehr unangenehm) ueber 0 (neutral) bis +10 (sehr angenehm) einzustufen.

Danach folgen vier getrennte Lernphasen, in denen Geräusche und Bilder in schneller Abfolge mehrmals hintereinander dargeboten werden. Bestimmte Geräusche kuendigen dabei jeweils bestimmte Bilder mehr oder weniger zuverlässig an. Insgesamt werden vier verschiedene Ereignisse auftreten:

1. Das Geräusch und das Bild werden zusammen dargeboten.

2. Das Geräusch ertoent, aber es erscheint kein Bild.

3. Das Bild erscheint ohne dass es durch ein Geräusch angekuendigt wurde.

4. Weder Geräusch noch Bild werden dargeboten.

Alle vier Ereignisse werden Sie fuer die verschiedenen Paare von Bildern und Geräuschen mehrmals beobachten. Ihre Aufgabe ist es, zu lernen, wie zuverlässig jedes einzelne Bild durch eines der Geräusche angekuendigt wird. Nachdem ein Block von Darbietungen (ca. 3 Minuten) beendet ist, werden wir Sie bitten, zunächst das jeweils zu einem Geräusch gehoerende Bild anzugeben und schließlich die Stärke des Zusammenhangs fuer jedes Geräusch-Bild-Paars auf einer Skala von 0 (kein Zusammenhang) bis 100 (starker Zusammenhang) einzeln einzustufen.

Ein starker Zusammenhang bedeutet, dass das Ertoenen eines Geräuschs das Erscheinen eines Bilds vorhersagt: Die meiste Zeit, wenn das Geräusch ertoente, erschien auch das Bild und die meiste Zeit, wenn das Geräusch nicht ertoente, erschien auch das Bild nicht. Ein schwacher Zusammenhang bedeutet, dass ein Bild nach einem Geräusch ebenso oft erschien wie ohne das Geräusch. Das Bild konnte durch das Geräusch also nicht vorhergesagt werden. überlegen Sie bitte fuer jedes Paar, ob der Zusammenhang eher stark oder schwach ist.

Haben Sie Fragen?

Instructions presented prior to the baseline rating phase

Herzlich Willkommen zu unserem Versuch! Vielen Dank, dass Sie sich bereit erklärt haben, teilzunehmen. Wir möchten Sie nun bitten, eine Reihe von Geräuschen danach zu bewerten, wie angenehm bzw. unangenehm Sie diese empfinden. Sie werden jeweils zuerst ein Geräusch hören und anschließend eine Skala sehen, die von -10 bis +10 reicht: -10 = "sehr unangenehm" 0 = "neutral" +10 = "sehr angenehm" Bitte bewerten Sie jedes Geräusch möglichst spontan indem Sie mit der linken Maustaste auf ein Feld des Skala klicken. Wenn Sie das Geräusch nochmals hören möchten, können Sie auf das kleine Quadrat links oben klicken. Denken Sie bei der Bewertung aber bitte nicht lange nach, sondern verlassen Sie sich auf Ihren ersten Eindruck. Falls Sie noch Fragen haben, dann können Sie sich jetzt an die Versuchsleitung wenden. Setzen Sie dann bitte die Kopfhörer auf und drücken Sie die Leertaste, um zu beginnen.

Instructions presented prior to the first learning block

Lernphase I

Sie werden nun verschiedene Geräusche und Bilder mehrmals hintereinander

```
hören und sehen. Jedes Geräusch kündigt dabei jeweils ein bestimmtes Bild
mehr oder weniger zuverlässig an. Ihre Aufgabe ist es, zu lernen, wie gut
jedes der Ge- räusche ein bestimmtes Bild vorhersagt. Achten Sie dabei
bitte nicht nur auf die Fälle, in denen Sie ein bestimmtes Bild nach einem
Geräusch sehen, sondern achten Sie auch auf die Fälle, in denen kein Bild
nach demselben Geräusch er- scheint oder das Bild ohne Ankündigung durch
ein Geräusch erscheint. Sie werden anschließend gebeten, die Stärke des
Zusammenhangs für jedes Geräusch-Bild-Paar auf einer Skala von 0 bis
100 anzugeben. Haben Sie noch Fragen? Drücken Sie die Leertaste um zu
starten.
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Instructions presented after the first learning block

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Testphase I
-----------
Nun folgt der Test zu den bisher dargebotenen Geräuschen und Bildern. Sie
werden jeweils eines der Geräusche hören. Stufen Sie bitte zuerst ein, wie
angenehm bzw. unangenehm Sie das Geräusch finden. Wählen Sie dann das Bild
aus, das mit dem Geräusch gekoppelt war. Wählen Sie bitte auch ein Bild
aus, wenn Sie sich nicht ganz sicher sind. Stufen Sie anschließend auf
einer Skala von 0 (= kein Zusammenhang) bis 100 (= starker Zusammenhang)
ein, wie zuverlässig das Bild durch das jeweilige Geräusch Ihrer Meinung
nach vorhergesagt wurde. Haben Sie noch Fragen? Drücken Sie die Leertaste,
um zu beginnen.
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Index of authors

Abramson, L. Y., 121, 131, 134
Allan, L. G., 23, 46, 49, 55, 58, 119, 121, 127, 131, 132, 134
Allen, C. T., 23, 58
Alloy, L. B., 121, 131, 134
Anderson, J. R., 55, 58, 119, 134
Antos, S. J., 98, 115

Baddeley, A., 91, 115
Baddeley, A. D., 43, 58, 91, 92, 111, 115
Baeyens, F., 21–24, 27–31, 34, 44, 45, 47, 52–54, 58–64, 72, 73, 83, 84, 89, 90, 108, 110–113, 118–120, 122, 126, 130, 132, 133, 135–137
Baker, A. G., 46, 69, 121, 139
Banbury, S., 91, 111
Banis, H. T., 26, 61
Baron, R. M., 80, 83
Beaman, C. P., 92, 114
Beckers, T., 24, 31, 54, 59, 72, 83
Bernstein, I. L., 23, 59
Biferno, M. A., 25, 60, 89, 112
Booker, J., 57, 63
Bradley, M. M., 46, 65, 121, 137
Brainard, D. H., 75, 83, 94, 111, 123, 135
Brewer, W. F., 25, 59
Brown, K. J., 22, 27, 31, 33, 56, 62, 89, 110, 112, 118, 136
Brunstorm, J. M., 43, 59, 91, 111
Byrnes, D., 22, 68

Carey, E., 22, 62, 130, 136
Chatlosh, D. L., 46, 69, 121, 131, 139
Clark, R. E., 26, 59
Cleeremans, A., 26, 66
Cohen, J., 48, 59
Colle, A., 91, 112
Conrad, M., 43, 69, 94, 116
Coppens, E., 23, 60
Corneille, O., 27, 61, 66, 68, 73, 85, 90, 115, 116, 119, 138, 139
Craill, L., 22, 62, 130, 136
Creelman, C. D., 127, 137
Crombez, G., 21, 22, 24, 31, 58, 59, 63, 64, 73, 84, 90, 108, 111, 113, 118, 130, 135, 137

Crump, M. J. C., 121, 134
Cuthbert, B. N., 46, 65, 121, 137

Davey, G. C. L., 25, 28, 32, 60, 62, 120, 126, 130, 135, 136
Davis, C., 57, 63
Dawson, M. E., 22, 25–27, 41, 60, 61, 65, 67, 72, 84, 89, 90, 109, 112, 119, 131, 135
De Viqo, P., 24, 59, 72, 83
De Clercq, A., 24, 69
Dedonder, J., 61
Defares, P. B., 22, 64
De Houwer, J., 21–25, 27, 28, 33, 34, 38, 42, 45, 47, 52–54, 57, 61, 64, 65, 72, 73, 84, 85, 89, 90, 108, 109, 111–113, 115, 118, 120–122, 133, 135–137
Destrebecqz, A., 26, 66
Díaz, R., 24, 62
Dick, K., 22, 62
Dickinson, A., 22, 27, 31, 33, 56, 62, 89, 110, 112, 118, 119, 121, 131, 136, 138
Dirikx, T., 63
Dwyer, M. D., 22, 24, 31, 54, 62

Eelen, P., 22–24, 27–31, 34, 45, 52, 58–61, 63, 69, 72, 83, 84, 89, 90, 108, 111, 112, 118, 119, 126, 130, 135
Eifert, G.-H., 22, 23, 62, 130, 136
Elek, S. M., 46, 69, 121, 139
Ellermeier, W., 44, 62, 69, 91, 113, 116
Engle, R. W., 23, 68, 89, 116
Evenden, J., 119, 136

Farley, L. A., 92, 115
Fazio, R. H., 23, 27, 29, 32, 62, 64, 66, 72, 84, 90, 113, 120, 137
Field, A. P., 21, 27, 28, 32, 40–42, 44, 61, 62, 73, 74, 81–84, 89, 90, 108–110, 112, 113, 119, 120, 130, 135, 136
Forster, K., 57, 63
Francken, G., 24, 69
Fulcher, E. P., 21, 22, 27, 28, 31, 33, 41, 42, 44, 45, 52, 56, 57, 63, 72–74, 80, 83, 84, 89, 90, 92, 108–110, 113, 118, 119, 131, 136
Furedy, J. J., 25, 60, 109, 112

Gast, A., 27, 63, 82, 84, 90, 113
Ghani, J., 44, 69, 91, 116
Giurfa, M., 132, 137
Grabitz, H.-J., 22, 27, 28, 31, 63, 89, 109, 110, 113, 130, 136

Hall, G., 26, 66
Hamm, A. O., 24, 25, 63
Hammerl, M., 21, 22, 27, 28, 31, 33, 41, 42, 44, 45, 52, 56, 57, 63, 72–74, 80, 83, 84, 89, 90, 92, 108–110, 113, 119, 130, 131, 136
Hannah, S. D., 121, 134

Hellbrück, J., 91, 114
Hendrickx, H., 27, 61, 72, 84, 90, 112
Hermans, D., 22–24, 31, 59, 63, 72, 83, 118, 135
Higgs, S., 43, 59, 91, 111
Hofmann, W., 21, 27, 33, 45, 64, 73, 74, 82–84, 90, 113, 118–120, 130, 137
Hugdahl, K., 24, 26, 64
Hughes, R., 91, 113

Jaanus, H., 22, 64
Jacobs, A., 43, 69, 94, 116
Jacoby, L. L., 57, 64
Janiszewski, C. A., 23, 58
Jarratt, F., 22, 62
Jenkins, H. M., 46, 49, 58, 119, 121, 134
Johnsrude, I. S., 64
Jones, C. R., 32, 52, 64, 72, 84, 90, 113, 120, 130, 137
Jones, D. M., 91, 92, 111, 113, 114

Kamin, L. J., 24, 64
Kardes, F. R., 32, 62
Kenny, D. A., 80, 83
Kilcher, H., 91, 114
Kimble, G. A., 20, 64
Klatte, M., 91, 114
Kornbrot, D. E., 121, 138
Kuppens, T., 61

Lachnit, H., 20, 65, 132, 137
Lang, P. J., 46, 65, 121, 122, 137
Langer, T., 44, 52, 53, 69, 89, 116
LeCompte, D. C., 91, 114
Levey, A. B., 21, 22, 27, 30, 44, 52, 53, 65, 72, 84, 89, 109, 114, 118, 120, 132, 137
Lewis, V., 92, 111
Lipp, O. V., 24, 25, 27, 29, 65, 66, 85
Lober, K., 132, 137
Lovibond, P. F., 25, 28, 29, 31, 34, 52, 53, 65, 69, 72, 85, 89, 90, 109, 114–116, 119, 120, 137, 139
Ludwig, I., 132, 137
Luminet, O., 27, 66, 73, 85, 90, 115, 119, 138

Macken, W. J., 91, 92, 111, 114
Mackintosh, N. J., 26, 65
Macmillan, N. A., 127, 137
Manns, J. R., 26, 59
Marinkovic, K., 25, 26, 65, 67
Martin, I., 21, 22, 27, 30, 44, 52, 53, 65, 72, 84, 89, 109, 114, 118, 120, 132, 137
Mason, V., 24, 65
Miles, C., 91, 114
Millman, L., 21, 67
Mitchell, C. J., 25–29, 33, 53, 65, 69, 72, 83, 85, 90, 109, 115, 116, 119, 120, 137, 139
Moore, A. C., 27, 40–42, 44, 62, 73, 74, 81–84, 89, 90, 108–110, 113

Msetfi, R. M., 121, 137, 138
Murphy, R. A., 121, 137–139

Nagengast, B., 23, 27, 28, 31, 37, 45, 52, 56, 69, 72, 85, 89, 110, 116, 119, 139
Neath, I., 92, 115
Neely, C. B., 91, 114
Neumann, D. L., 24, 65
Neunaber, D. J., 131, 139

O'Connor, C., 22, 62, 130, 136
Ohira, H., 98, 115
Öhman, A., 24–26, 29, 64–66, 69, 90, 115
Olson, M. A., 23, 27, 29, 32, 64, 66, 72, 84, 90, 113, 120, 137
Orthony, A., 98, 115
Owen, A. M., 64
Oyama, M., 98, 115

Page, J., 91, 114
Pavlov, I. P., 20, 66
Pearce, J. M., 26, 66
Pearson, S. M., 121, 138
Pelli, D. G., 75, 85, 94, 115, 123, 138
Perruchet, P., 26, 66
Perugini, M., 21, 64, 73, 84, 90, 113, 118, 137
Pleyers, G., 27, 40–42, 45, 49, 66, 73, 74, 81, 83, 85, 90, 93, 98, 103, 108–110, 115, 119, 131, 138
Powell, M. C., 32, 62
Priluck, R. L., 23, 68
Purkis, H. M., 25, 27, 29, 66, 85

Rachman, S., 24, 67
Razran, G. H. S., 22, 30, 67, 89, 115
Reinhard, G., 132, 137
Rescorla, R. A., 23, 25, 31, 53, 67, 118, 122, 138
Rissling, A. J., 22, 60, 90, 112, 119, 135
Rothermund, K., 27, 63, 82, 84, 90, 113
Rozin, P., 21, 22, 67, 68
Ruiz, G., 24, 62
Ruys, K. I., 56, 67

Salamé, P., 91, 115
Sanbonmatsu, D. M., 32, 62
Schacter, D. L., 57, 63
Schell, A. M., 22, 25, 26, 60, 61, 65, 67, 90, 112, 119, 135
Seligman, M. E. P., 26, 67
Shanks, D., 119, 136
Shanks, D. R., 20, 21, 25, 26, 28, 29, 31, 34, 52, 53, 65, 67, 68, 72, 85, 89, 114, 119, 121, 137, 138
Sheu, C.-F., 55, 58, 119, 134
Shimp, T. A., 23, 68, 89, 116
Siegel, S., 121, 134
Simpson, J., 121, 137, 138
Soares, J. J. F., 29, 66
Speiser, H. R., 109, 116
Squire, L. R., 26, 59

Staats, A. W., 22, 27, 30, 68, 91, 109, 116, 130, 138
Staats, C. K., 22, 27, 30, 68, 91, 109, 116, 130, 138
Stahl, C., 27, 29, 41, 45, 68, 73, 81, 85, 90, 110, 116, 119, 131, 133, 138, 139
Stapel, D. A., 56, 67
St. John, M. F., 26, 28, 68, 119, 138
Stroop, J. R., 57, 68
Stuart, E. W., 23, 68, 89, 116
Surprenant, A. M., 92, 115
Sweldens, S., 23, 68

Tangen, J. M., 121, 134
Thomas, S., 21, 61, 89, 112, 118, 136
Thorndike, E. L., 25, 68
Till, B. D., 23, 68
Todrank, J., 22, 68
Trasselli, C., 23, 69
Tremblay, S., 91, 111
Turner, T. J., 98, 115

Unkelbach, C., 27, 29, 41, 68, 73, 81, 85, 90, 110, 116, 119, 138, 139

Vaitl, D., 24, 25, 63
Vallar, G., 92, 111
Vallée-Tourangeau, F., 121, 132, 139
Van den Bergh, O., 22, 23, 27–31, 34, 45, 52, 58, 59, 63, 72, 83, 89, 108, 111, 118, 119, 126, 130, 135
Vandenbulcke, M., 60
Van Paesschen, W., 60
Vansteenwegen, D., 22, 24, 30, 31, 55, 59–61, 63, 69, 118, 135
Vervliet, B., 24, 69
Vo, M.-L., 43, 69, 94, 116

Wagner, A. P., 25, 67
Walther, E., 23, 27, 28, 31, 37, 41, 44, 45, 52, 53, 56, 69, 72, 85, 89, 110, 116, 119, 120, 139
Wardle, S. G., 29, 69, 90, 116, 119, 139
Wasserman, E. A., 46, 49, 69, 121, 131, 139
Watson, J. B., 20, 25, 69
Webster, M. W., 23, 59
Welsh, A., 91, 112
White, N. M., 64
Wiens, S., 29, 69
Wilcox, R., 22, 60, 90, 112, 119, 135
Wilson, J. R., 91, 114
Winton, W. M., 98, 115
Wrzesniewski, A., 22, 68

Yzerbyt, V., 27, 61, 66, 73, 85, 90, 115, 119, 138

Zhao, W. V., 64
Zimmer, H. D., 109, 116
Zimmer, K., 44, 62, 69, 91, 95, 104, 113, 116
Zwaan, E. J., 22, 64

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Eidesstattliche Erklärung

Hiermit versichere ich, dass ich die vorliegende Arbeit mit dem Titel

"Cognitive Factors in Evaluative Conditioning: The Role of Attention, Working Memory, and Contingency Appraisal"

selbstständig, ohne Hilfe Dritter und nur mit den angegebenen Quellen und Hilfsmitteln angefertigt habe. Alle Stellen, die aus anderen Werken im Wortlaut oder dem Sinne nach entnommen wurden, sind als solche kenntlich gemacht.

Diese Arbeit hat in gleicher oder ähnlicher Form noch keiner Prüfungsbehörde vorgelegen.

Darmstadt, den 04. März 2011

Florian Kattner

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