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Mindfulness reduces habitual responding based on implicit knowledge: Evidence from artificial grammar learning

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ABSTRACT

Participants were unknowingly exposed to complex regularities in a working memory task. The existence of implicit knowledge was subsequently inferred from a preference for stimuli with similar grammatical regularities. Several affective traits have been shown to influence AGL performance positively, many of which are related to a tendency for automatic responding. We therefore tested whether the mindfulness trait predicted a reduction of grammatically congruent preferences, and used emotional primes to explore the influence of affect. Mindfulness was shown to correlate negatively with grammatically congruent responses. Negative primes were shown to result in faster and more negative evaluations. We conclude that grammatically congruent preference ratings rely on habitual responses, and that our findings provide empirical evidence for the non-reactive disposition of the mindfulness trait.

1. Introduction

1.1. Implicit learning

Implicit learning is the ability to acquire knowledge of complex regularities without conscious intent or awareness (Seger, 1994). Skill learning, habit learning and procedural learning are related forms of implicit learning. Implicitly acquired knowledge is typically not accessible or represented explicitly (e.g., in a language-based manner) in the form of facts (knowing *that*). Nevertheless, implicit knowledge (knowing *how*), underlies much of our behavioral repertoire – from riding a bike to blind typing – and is important in understanding the world and people around us, from musical appreciation to navigating the complexities of language (Stadler & Frensch, 1998). In the lab, implicit knowledge is often inferred from faster processing of structured stimuli, that are comparable (on some stimulus dimension) to those individuals previously have been exposed to (in e.g. real life or in the lab). In addition, evidence for implicitly acquired knowledge is commonly observed through the development of a preference or 'gut-feeling' for similarly structured stimuli, typically in the absence of verbal access to what is known.

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1.2. Artificial grammar learning

Artificial grammar learning (AGL) is probably the most studied paradigm for investigating implicit learning. The paradigm distinguishes an *acquisition phase* and *test phase* (Cleeremans, Destrebecqz, & Boyer, 1998; Forkstam & Petersson, 2005b). In the acquisition phase, participants are exposed to a set of symbol sequences generated from a formal grammar (i.e., a complex rule system), often in the form of a short term memory task. In the subsequent test phase subjects are often first debriefed about the existence of an underlying complex set of rules and instructed to classify a novel set of sequences according to grammaticality, based on guessing or 'gut feeling'. It is a robust and well-replicated finding that subjects perform significantly above chance on this type of task with little, if any, explicit knowledge about their classification capacity (Cleeremans et al., 1998; Forkstam, Elwér, Ingvar, & Petersson, 2008; Forkstam & Petersson, 2005b). In fact, when subjects are not informed about the existence of a grammar, similar classification performance can be observed using forced-choice preference ratings (like/dislike) (Folia et al., 2008; Forkstam et al., 2008). There is good evidence that the frontal cortex and the basal ganglia (fronto-striatal circuits) are involved in implicit learning in humans. This has been characterized in patient (lesion) studies (Forkstam & Petersson, 2005b; Seger, 1994), functional neuroimaging studies (Forkstam, Hagoort, Fernandez, Ingvar, & Petersson, 2006; Lieberman, Chang, Chiao, Bookheimer, & Knowlton, 2004; Rose, Haider, Weiller, & Buchel, 2002) and brain stimulation studies (de Vries et al., 2010). Furthermore, in healthy volunteers transcranial magnetic stimulation of Broca's area has causal effects on classification after implicit learning of an artificial grammar (Udden et al., 2008). Imaging studies of AGL repeatedly find activations in the basal ganglia, in particular the striatum (Forkstam et al., 2006; Petersson, Folia, & Hagoort, 2010). Taken together these findings suggest a common neural substrate of different forms of implicit learning (for a review see (Forkstam & Petersson, 2005a; Yin & Knowlton, 2006)).

1.3. The role and mechanisms of affect on preference for grammaticality

While implicit knowledge acquisition is a robust and well established phenomenon, a conclusive account of how such knowledge is expressed in implicit preference or explicit endorsement rates does not yet exist. Gordon and Holyoak (1983) proposed a role for the mere-exposure effect (Zajonc, 1968). In the mere-exposure effect, repeated (unreinforced) exposure results in positive affect towards those stimuli (for an overview see Bornstein (1989)). In the *structural* mere-exposure effect grammatical sequences are processed more easily during classification due to the previous grammatical stimuli. Similarly to the traditional mere-exposure effect, this increased fluency is then interpreted as a preference. Interestingly, both Newell and Bright (2001) and Zizak and Reber (2004) showed that when classification sequences are presented with different or degraded surface features, performance based on preference is abolished while explicit ratings of grammaticality remain unimpaired. This suggests that familiarity with lower level features is required before *structural* mere-exposure effects can occur on more complex (grammatical) levels of stimulus processing. Scott and Dienes (2010) showed that while perceptual fluency influences preference judgments, under controlled conditions this provides participants only with a 'dumb' heuristic. In fact, preference judgments were shown to be based on perceptual fluency when participants had only very limited time to process the sequences and more accurate evaluations (based on familiarity) could not be made. Although these studies show that fluency can influence preference ratings, they do not explain in what way preference ratings are related to the implicitly acquired grammar. The question remains whether preference for grammatical sequences is the result of a positive (affective) association with the representation of the grammar, or whether preference instead should be understood as a response outcome of non-affective cognitive processes.

1.4. Feelings vs. affect

It is important at this point to consider 'affect' separately from 'feeling'. Cognitive appraisals and motivational processes are intimately involved in the former, resulting in action tendencies that do not necessarily involve subjective, felt experiences (cf., Frijda (1986), Damasio (2003) and Berridge and Winkielman (2003)). Preference judgments made in AGL classification might therefore not express actual preferences (i.e., conscious feeling states towards (non-)grammatical stimuli) but rather reflect motivational processes that result in automatically endorsing certain stimuli rather than others. In this study, we directly tested whether an affective component is involved in AGL classification by using masked affective primes. Furthermore, we investigated the relationship between individual differences in AGL performance and mindfulness, describing an individual's disposition to disengage from automatic reactions and attend to internal and external stimuli in a non-judgmental and non-reactive way.

1.5. Mindfulness state and meditation

Mindfulness had been formally defined as 'paying attention in a particular way: on purpose, in the present moment, and non-judgmentally' (Kabat-Zinn, 1994), 'the state of being attentive to and aware of what is taking place in the present', Brown and Ryan (2003) or in similar vein Bishop et al. (2004). It prevents one from '...falling prey to automatic judgments or reactivity' (Segal, Williams, & Teasdale, 2002). Often contrasted to the conceptual mode of processing, a mindful mode of processing involves a receptive state of mind wherein attention is kept to bare registering of the facts observed. This permits the individual to 'be present' in reality as it is, rather than to automatically react to or habitually process it through conceptual filters (e.g. Brown and Ryan (2003) and Bishop et al. (2004)). This is not an uncontroversial claim to make since concepts, labels and judgments are often imposed automatically on all stimuli encountered (e.g. Bargh and Chartrand (1999)). However, evidence is accumulating that practicing mindfulness suspends automatic processes such as interference in the Stroop task (Moore & Malinowski, 2009), reduces cognitive rigidity in the Einstellung water jar task (Greenberg, Reiner, & Meiran, 2012) and improves cognitive (Heeren, Van Broeck, & Philippot, 2009) and executive flexibility (Hodgins & Adair, 2010). The claim that these effects are the result of attentional training is supported by findings showing that mindfulness training improves attention-orienting and alerting processes (Jha, Krompinger, & Baime, 2007; Jha, Stanley, Kiyonaga, Wong, & Gelfand, 2010; van den Hurk, Giommi, Gielen, Speckens, & Barendregt, 2010), decreases the attentional blink effect (Slagter et al., 2007) and increases attentional stability (Lutz et al., 2009).

1.6. Mindfulness in clinical interventions

Mindfulness techniques have been successfully implemented within clinical interventions, e.g. in patients with recurrent major depression (see Chiesa and Serretti (2011) and Piet and Hougaard (2011) for recent reviews), in those suffering from residual negative ruminations (Kingston, Dooley, Bates, Lawlor, and Malone (2007) and Ramel, Goldin, Carmona, and McQuaid (2004)), generalized anxiety (Roemer & Orsillo, 2002) and attentional deficits in ADHD (Zylowska et al., 2008). Although it is argued that its clinical efficaciousness relies partly on the development of a non-judgmental and non-reactive disposition (e.g. Brown, Ryan, and Creswell (2007) and Teasdale et al. (2002)), empirical work investigating this connection remains scant. To the best of our knowledge, only Raes, Dewulf, Van Heeringen, and Williams (2009) showed that the mindfulness trait correlated negatively with cognitive reactivity to sad mood, and importantly, that this cognitive reactivity was reduced after mindfulness training.

1.7. The mindfulness trait and how to measure it

There is a growing consensus that the mindfulness disposition is an inherent capacity (Brown & Ryan, 2003; Kabat-Zinn, 2003; Kuhlman, 2002), which can be measured in the general non-meditating population using self-report questionnaires (see Baer, Smith, Hopkins, Krietemeyer, and Toney (2006), Baer (2011) and Brown and Ryan (2004), but also see Grossman and Van Dam (2011) for a critical perspective) with good to excellent test–retest reliability (Veehof, Ten Klooster, Taal, Westerhof, & Bohlmeijer, 2011). Self-report questionnaires range in complexity from one scale questionnaires (Brown & Ryan, 2003) to the Five Factor Mindfulness Questionnaire (FFMQ, (Baer et al., 2006), for an overview see Baer (2011)). The FFMQ is the result of a factor analysis of five previously developed questionnaires and has good internal consistency as well as convergent and discriminant relationships with other constructs. It correlates positively with meditation experience and with standard personality traits such as *openness to experience*, while correlating negatively with neuroticism and absent-mindedness as well as clinically relevant traits such as difficulties in emotional regulation, alexithymia and dissociation (Baer et al., 2006, 2008).

1.8. Individual difference in affective reactions, general cognition and implicit learning

Evidence for the role of affective states and traits in implicit learning performance or mere-exposure effects, comes from studies investigating individual differences. The mere-exposure effect has been shown to be under a positive influence of negative affective state (Harmon-Jones & Allen, 2001) as well as personality traits such as proneness for boredom (Bornstein, Kale, & Cornell, 1990) and intolerance of ambiguity (Crandall, 1968). Importantly, AGL performance seems to be independent of cognitive abilities such as general intelligence and working memory capacity (Gebauer & Mackintosh, 2007; Reber, Walkenfeld, & Hernstadt, 1991). Kaufman et al. (2010), however, found a positive correlation between implicit learning performance on the serial response time task (SRT) and processing speed, verbal reasoning and language abilities. Furthermore, they found a positive relationship with a Big Five personality style characterized by Openness. Notably, Norman, Price, and Duff (2006) and Norman, Price, Duff, and Mentzoni (2007) did not find such a relationship in their deterministic SRT task. Compelling evidence for the effect of an affective and motivational state of the individual comes from Proulx and Heine (2009), who showed an increased ability to identify grammatical sequences in an AGL task when participants had just read an anxiety-inducing short-story by Kafka or when they had argued against their self-unity. The authors interpreted their findings in terms of an increased desire to find and construct patterns after a meaning-threat. Finally, an influence of affective traits has also been found for the Iowa Gambling task, where neuroticism (Carter & Pasqualini, 2004) and trait anxiety (Schmitt, Brinkley, & Newman, 1999) correlated positively with performance.

Concluding, previous work has shown that, aside from general linguistic abilities, affective states and traits interact with implicit learning. In terms of clinical as well as non-clinical traits, affective processes and personality traits seem involved in implicit learning, including negative mood (Harmon-Jones & Allen, 2001), anxiety (Schmitt et al., 1999), neuroticism (Carter & Pasqualini, 2004) and meaning threats (Proulx & Heine, 2009). Importantly these display a remarkable overlap with states and traits negatively associated with mindfulness (described in Sections 1.5–1.7). In other words, implicit learning seems to benefit from a disposition to respond habitually and reactively, traits strikingly opposite to the mindful disposition.

1.9. Manipulation of affective states: Affective primes

The causal effect of feelings on implicit learning can only be investigated by controlled experiments in which affect is systematically manipulated. Besides Proulx and Heine (2009) we know of no such studies. It is well established that masked semantic primes reliably induce congruent semantic facilitation on subsequent target stimuli (for a review see van den Bussche, van den Noortgate, and Reynvoet (2009) and Kouider and Dehaene (2007)). Furthermore, masked emotional faces have been shown to result in congruent affective judgments on subsequent ideographs (Rotteveel, de Groot, Geutskens, & Phaf, 2001). In the current study were therefore used masked affective primes to explore whether primed affect influences retrieval of implicit knowledge.

1.10. Experiment

Participants performed a 5 day working memory task. Unbeknownst to them, sequences were generated according to complex rules. On three occasions novel items were classified according to preference (like/dislike): at baseline, after working memory sessions, and on the last day of the experiment. After the last preference task participants were debriefed about the existence of a complex rule system behind the working memory stimuli. They were then instructed to perform grammaticality judgments (grammatical/non-grammatical) on a new stimulus set. Also unknown to the participants, all target stimuli (classification sequences) were preceded by subliminally presented (backward and forward masked) neutral, positive (happy) or negative (disgust) faces. To estimate the degree of explicit knowledge about the grammar after the completion of the experiment, participants answered a structured multiple-choice questionnaire of the grammar's bigram state transitions. Finally, participants filled in the FFMQ.

1.11. Hypothesis

We hypothesized that individual endorsement rates (the preference for grammatical sequences over non-grammatical sequences, and grammaticality classification performance) would be negatively correlated with FFMQ scores. To control for a confounding relationship between mindfulness and verbal or general cognitive abilities, we tested for a correlation of mindfulness with working memory performance and the ability of participants to make grammatical rules explicit after completion of the experiment. Explicit knowledge was expected to correlate positively with grammatical classification performance. Lastly, we predicted that sequences preceded by positive primes would result in more positive judgments (of preference and grammaticality), while sequences preceded by negative primes were expected to result in more negative judgments.

2. Method

2.1. Participants

Eighteen university students volunteered to participate in the study (13 females, 5 males, mean age ± standard deviation = 22.2 ± 6.7 years) for course credits. They were all pre-screened for relevant medical history, medication use, drug abuse, head trauma, neurological or psychiatric illness, and family history of neurological or psychiatric illness. All subjects had normal or corrected-to-normal vision. All participants gave written informed consent according to the Declaration of Helsinki.

2.2. Stimulus material

We generated 569 grammatical (G) sequences from the Reber grammar (see Fig. 1) with a sequence length of 5–12 symbols (M, S, V, R and X). A robust finding in the AGL literature is that subjects are highly sensitive to chunks of two or three

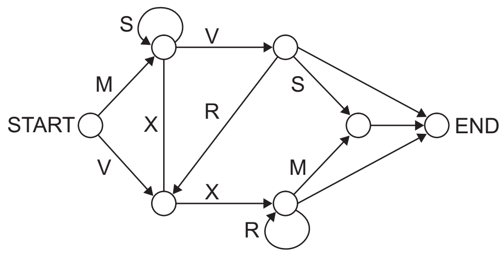

Fig. 1. Implicit grammar underlying acquisition and classification sequences. The transition graph of the grammar. A grammatical sequence is generated by concatenating letters of valid transitions (arrows), going from the start node to the end node.

adjacent letters (bi- and trigrams). Although early in acquisition a sensitivity to these chunks indicates an initial shallow processing of the grammar, at the end of acquisition the grammatical status of the complete sequence has become a better predictor of classification (Forkstam, Elwér, Ingvar, & Petersson, 2008). In this study we controlled for differences in the associative chunk strength (ACS), operationalized as the average chunk strength across all possible subsequences of two or three letters within the acquisition sequences. We calculated the complete associative chunk strength for each sequence in relation to the complete set of 569 sequences (c.f. Knowlton and Squire (1996), Meulemans and Van der Linden (1997) and Udden et al. (2008)). In an iterative procedure 100 sequences were randomly selected and tested with respect to its ACS content in order to generate the acquisition set which was representative in terms of ACS in comparison to the complete sequence set. The classification sets were subsequently derived from the remaining 469 grammatical sequences and for each of these a non-grammatical sequence was derived by a switch of letters in two non-terminal positions. Finally, 6 sets of 64 sequences were randomly selected from the 469 grammatical and their matched 469 non-grammatical sequences in an iterative procedure, in order to generate classification sets consisting of 50% grammatical and non-grammatical sequences, as well as 50% high and low ACS sequences relative to ACS information in the acquisition set and independent of grammaticality status. Working memory stimuli were presented in Arial (30 points font size) on a screen resolution of 1280 × 1024, 75 cm in front of the subject. Classification stimuli were presented in an identical setup. For all classification sets, grammatical and non-grammatical sequences did not differ in terms of ACS.

2.3. Primes

Frontal-facing neutral, happy and disgusted faces from the Averaged Karolinska Directed Emotional Faces set (Lundqvist, Flykt, & Ohman, 1998; Oosterhof & Todorov, 2008) were used, consisting of (8 bit, 562 × 762 px) grayscale averages of 70 individuals (35 males and 35 females) showing emotional expressions. The forward mask was constructed by superimposing rotated pieces of the neutral, positive and negative primes. The resulting mask scrambled the contours of the face as well as details of the emotional expression, while keeping gradients of the original images. The backward mask was a horizontally flipped version (mirrored over the vertical axis) of the forward mask. Masks were presented for 50 ms (three frames at 60 Hz), sandwiching the prime that was presented for 33 ms (two frames). Primes and masks were presented in the middle of the screen, spanning 20.5 by 24.5 cm, or 15.7 by 18.7° of visual angle.

2.4. Software

The experiment was programmed in Presentation (Neurobehavioural Systems, neurobs.com). All analyses were conducted in Matlab (mathworks.com) and PASW Statistics 18 (SPSS Inc., SPSS.com).

2.5. Questionnaires

To provide our participants with a continuous focus and to maintain the cover of the working memory (WM) task, each WM-session was concluded with a short questionnaire in which they had to report all strategies that they used to memorize WM sequences.

In a post-experimental pen-and-paper questionnaire, participants were first asked if they noticed anything particular about the classification sequences and if they used any strategies to classify them. They were then probed about knowledge of the grammar through multiple choice questions about all grammar bigram transitions. This created a structured way for participants to explicate knowledge about bigrams without being provided with any details of the rules. The following thirteen questions were asked: What character(s) could the sequences start with? (five response options, one for every character); With what character(s) could the sequences end? (*idem*). What characters(s) could repeat themselves? (*idem*). What character(s) could follow character X? (one question for each character with four response options per question, excluding X). What character(s) could *not* follow X? (idem). The total score for every subject was calculated by adding one point for every hit and subtracting one point for every miss or false alarm. The score was then divided by the number of questions, resulting values that could range from −2.2 (worst performance) to 2.2. This score will be referred to as the Explicit Knowledge score, and EXPLICIT in the analysis. Mindfulness was measured using the Dutch version (de Bruin, Topper, Muskens, Bogels, & Kamphuis, 2012) of the 39 item Five Factor Mindfulness Questionnaire (FFMQ, Baer et al. (2006)).

3. Procedure

3.1. Procedure

The complete experiment spanned 5 days with one acquisition session each day. Before the first and after the second and fifth acquisition session a preference session was administered. After the last preference session participants were debriefed about the existence of underlying complex rules in the acquisition sequences (no details were given) and instructed to classify novel sequences in terms of grammaticality (yes/no) in a setup identical as the one used for the implicit classification sessions.

3.2. Working memory task

The acquisition task (~25 min) was presented as a short-term memory recall task. Every session twenty random items were drawn from the acquisition set, which was presented five times (a total of 100 presentations). During the acquisition task, the grammatical sequences were presented on the computer screen for 4 s. After the sequences disappeared, subjects had to repeat the sequence from memory by typing on a keyboard in a self-paced fashion. They were allowed to correct themselves using the backspace key. No performance feedback was provided.

3.3. Preference task

In the implicit classification task (~25 min) subjects were instructed to rate each sequence if they liked it or not, based on their immediate impression or 'gut feeling'. They were told that this task might appear odd in the beginning but that they might develop a preference and could rely on guessing until then. The classification sequence was presented centrally on the screen for 4 s, followed by a response screen to which they could respond with left or right button press on a custom made response box. Inter-trial-interval was 6 s during which a fixation cross was presented. Subjects were allowed as much time as they needed but were instructed to respond quickly and without much deliberation (i.e., using their 'gut feeling' or immediate impression). A self-paced break was included after every ten trials. The session was split halfway into two blocks between which the valence of the response-buttons was switched. The initial valence for the buttons was determined at random at every session and clearly displayed during every response screen and before each block.

3.4. Grammatical classification task

After the third and final preference session subjects were debriefed about the existence of a complex system of rules generating the acquisition sequences in the working-memory task. They were told that during the next classification session they would be presented with new sequences of which only half were constructed according to those rules, and the other half violated the rules in an unspecified way. They were then instructed to decide whether the (novel) sequences were grammatical or not, based on their immediate intuitive impression or whatever strategy they have been using in the previous sessions (i.e., familiarity). Subjects were allowed as much time as they needed but were instructed to respond quickly and without much deliberation. The implementation of the task was identical to that of the preference session.

3.5. Priming

Unbeknownst to the participants, every letter sequence in both classification tasks was preceded by a forward and backwards masked emotional face. The prime valence (neutral, positive or neutral) was determined *at random* for each presentation.

3.6. Analysis

Working memory (WM) performance over sessions was analyzed with repeated-measures ANOVA. WM performance (LEVENSHTEIN) was indexed by mean Levenshtein distance between target sequence and remembered sequence. Levenshtein distance is the minimum number of edits (insertion, deletion, or substitution of a single character) needed to transform one sequence into the other. Low Levenshtein distances therefore represent good WM performance, and high Levenshtein distance poor WM performance. For the preference session, responses (PREFERENCE) were modeled using a linear model with grammaticality status (GRAMMATICALITY) as independent factor, subject (SUBJECT) as random factor and, if applicable, session (SESSION) as fixed factor. Responses during the explicit classification session (CLASSIFICATION) were modeled similarly. For the sake of simplicity, effects of GRAMMATICALITY on PREFERENCE (GRAMMATICALITY × PREFERENCE) or CLASSIFICATION (GRAMMATICALITY × CLASSIFICATION) will be reported as endorsement rates. Endorsement rates will therefore represent *correct* judgments of grammaticality status, as well as preference for grammatical and disliking of non-grammatical sequences. In figures endorsement rates will be depicted in percentages of total number of responses in the relevant condition. Effects of positive vs. neutral primes (POS), and negative vs. neutral primes (NEG), on PREFERENCE, CLASSIFICATION and response time (RT), were analyzed using a linear model with SUBJECT as a random effect variable and GRAMMATICALITY and POS or NEG as a fixed factor. When applicable, LEVENSHTEIN, post-experiment explicit knowledge (EXPLICIT) and mindfulness (FFMQ-total or subscales) were entered as covariates in a full factorial mixed model. Correlations between covariates (FFMQ, LEVENSHTEIN and EXPLICIT) were calculated using Pearson's *r*.

4. Results

4.1. Acquisition task

Working memory performance improved over sessions ($F(4,48) = 53.3$, $p < .001$) and over repetitions ($F(4,48) = 27.9$, $p < .001$). Within-subject contrasts revealed that participants only improved in the first three sessions, showing no significant improvement between session 4 and 5 (session 1 vs. later: $F(1) = 135.7$ $p < .001$; session 2 vs. later: $F(1) = 23.4$, $p = .001$; session 3 vs. later: $F(1) = 10.5$, $p = .007$; session 4 vs. later: $F(1) = .206$, $p = .658$).

4.2. Preference task

Participants acquired a preference for grammatical sequences above non-grammatical sequences ($F(1) = 128$, $p < .001$), which increased with SESSION (see Fig. 2) as shown by the significant interaction of GRAMMATICALITY with SESSION ($F(2) = 53.1$, $p < .001$). Preference was not congruent with grammatical status in the first session ($F(1) = 1.42$, $p = .234$), but strongly so on the second ($F(1) = 13.6$, $p < .001$) and third session ($F(1) = 41.3$, $p < .001$). In the final implicit classification session (session 3), participants preferred grammatical sequences an average of 63.2% ($SD = 18.6\%$) over 36.4% ($SD = 18.0\%$) for non-grammatical sequences.

4.3. Grammatical classification task

Participants were able to distinguish grammatical from non-grammatical sequences in the explicit session ($F(1,2316) = 668$, $p < .001$), responding affirmative to 77.4% ($SD = 14.7\%$) of grammatical sequences, over only 29.9% ($SD = 15.6\%$) when sequences violated the grammar. Grammaticality judgments also took longer than preference judgments (preference: $M = 741$ ms, $SD = 16.7$ ms; grammaticality: $M = 906$ ms, $SD = 16.7$; $F(1) = 5.82$, $p = .028$).

4.4. Effect of working memory performance on endorsement rates

In the preference task, no significant effect of working memory performance (LEVENSHTEIN) on PREFERENCE ($F(16) = .069$, $p = .796$) or endorsement (GRAMMATICALITY × LEVENSHTEIN; $F(2284) = .874$, $p = .350$) was found (see Fig. 3C). In the grammatical classification task, LEVENSHTEIN had no effect on PREFERENCE ($F(16) = .922$, $p = .315$). LEVENSHTEIN did predict endorsement rate (GRAMMATICALITY × LEVENSHTEIN: $F(2298) = 66.4$, $p < .001$, see Fig. 4C).

4.5. Correlations between working memory performance, explicit knowledge and mindfulness

Explicit Knowledge correlated significantly with LEVENSHTEIN on the first WM session (EXPLICIT; $r = -.537$, $p = .022$), and on later sessions (session 2: $r = -.611$, $p = .007$; session 3: $r = -.580$, $p = .012$; session 4: $r = -.534$, $p = .041$; session 5: $r = -.642$, $p = .007$). As expected, FFMQ did not correlate with LEVENSHTEIN on the first WM session ($r = .320$, $p = .196$), showing only marginal trends towards significance on the last two sessions (uncorrected: session 2: $r = .274$, $p = .271$; session 3: $r = .024$, $p = .925$; session 4: $r = .486$, $p = .066$; session 5: $r = .438$, $p = .090$). Additional analysis showed that LEVENSHTEIN, when averaged over sessions, did not correlate with FFMQ ($r = .210$, $p = .402$). Only a marginal trend emerged when the correlation was based on a concatenation (not average) of LEVENSHTEIN of all five sessions ($r = .180$, $p = .089$). FFMQ did not correlate with EXPLICIT ($r = .003$, $p = .99$).

4.6. Individual differences in preference judgments

FFMQ showed no main effect on PREFERENCE ($F(1,16) = .164$, $p = .70$). As predicted, FFMQ did influence endorsement rates (FFMQ × GRAMMATICALITY × PREFERENCE: $F(1,2284) = 28.0$, $p < .001$), shown by the negative correlation between FFMQ and endorsement rates ($r = -.393$, see Fig. 3A). In contrast, EXPLICIT did not explain PREFERENCE (main effect: $F(1,16) = .128$, $p = .725$) or endorsement rates (EXPLICIT × GRAMMATICALITY: $F(1,2284) = .404$, $p = .525$, see Fig. 3B). To test

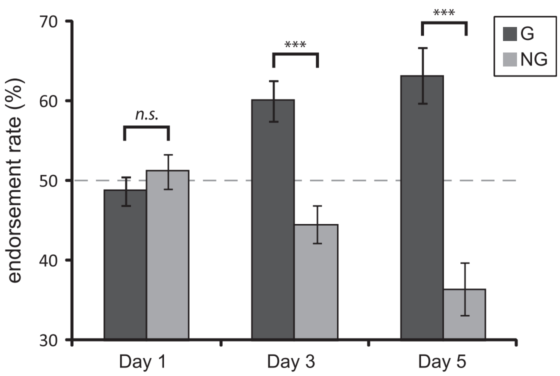

Fig. 2. Development of endorsement rates for the preference task. Endorsement rates for grammatical (G) and nongrammatical (NG) sequences for each day. At baseline (Day 1) no preference for grammaticality was shown. The sensitivity to the grammar was improved over Days 3 and 5. $^{***}p < .001$.

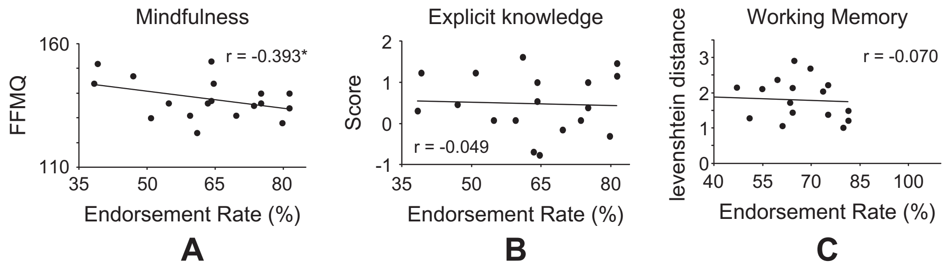

Fig. 3. Mindfulness reduces endorsement rate in preference task. Scatter plots showing correlations between endorsement rate and mindfulness (A), explicit knowledge (B) and working memory performance (C). Endorsement rates were calculated as the percentage of preferred grammatical sequences and disliked non-grammatical sequences, as a ratio of the total number of responses. $^*p < .05$, $^{**}p < .01$.

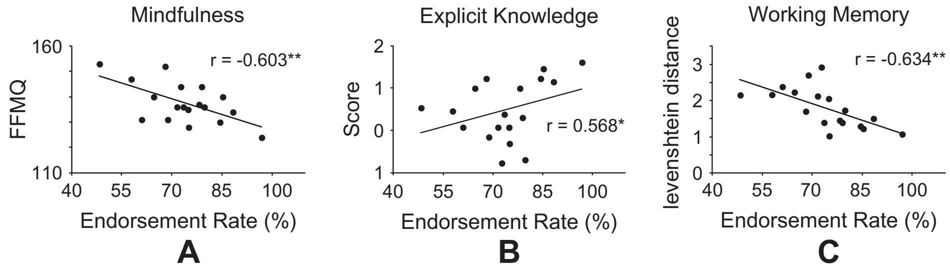

Fig. 4. Mindfulness, explicit knowledge and working memory correlate with endorsement rate in grammaticality task. Scatter plots showing correlation between endorsement rate and mindfulness (A), explicit knowledge (B) and working memory performance (C). Endorsement rates were calculated as the percentage of accepted grammatical sequences and rejected non-grammatical sequences, as a ratio of the total number of responses. $^*p < .05$, $^{**}p < .01$.

for a possible dependency (shared variance) between FFMQ and EXPLICIT, they were entered separately, resulting in similar outcomes (FFMQ: $F(1,2284) = 28.0$, $p < .001$, EXPLICIT: $F(1,2284) = .423$, $p = .516$).

We performed exploratory analysis to identify which subscales of the FFMQ most strongly influenced endorsement rates. Only the *non-judgmental* subscale would survive multiple-comparison corrections (*observe*: $F(1,2284) = .84$, $p = .028$; *describe* $F(1,2284) = 3.77$, $p = .052$; *acting with awareness*: $F(1,2284) = 3.38$, $p = .066$; *non-judgmental*: $F(1,2284) = 36.2$, $p < .001$; *non-reactivity*: $F(1,2284) = .031$, $p = .942$). The *non-judgmental* subscale also displayed the best predictor estimate, explaining most variance of all the subscales (*observe*: .001; *describe*: −.009; *acting with awareness*: −.01; *non-judgmental*: −.020; *non-reactivity*: −.001).

4.7. Individual differences in grammaticality judgments

Both FFMQ as well as EXPLICIT showed a significant effect on endorsement rates (FFMQ: $F(1,2284) = 28.01$, $p < .001$, see Fig. 4A; EXPLICIT: $F(1,2298) = 18.6$, $p < .001$, see Fig. 4B), caused by a negative correlation with FFMQ ($r = -.603$), and a positive correlation with EXPLICIT ($r = .568$). To control for a possible influence of LEVENSHTEIN on the negative correlation between FFMQ and endorsement rates, we entered LEVENSHTEIN as a control variable in a partial correlation analysis. The negative correlation between FFMQ and endorsement rates remained large and statistically significant ($r = -.545$, $p = .024$).

Similarly as for the preference session, the subscales of the FFMQ were separately tested (*observe*: $F(1,2299) = 14.1$, $p < .001$); *describe*: $F(1,2298) = 22.9$, $p < .001$; *acting*: $F(1,2298) = 7.27$, $p = .007$; *non-reactivity*: $F(1,2294) = 0.916$, $p = .339$; *non-judgmental*: $F(1,2298) = 9.20$, $p = .002$. None showed a significant main effect. The *describe* and *observe* subscale showed the best predictor estimates (*observe*: −.017; *describe*: −.019; *acting with awareness*: −.013; *non-judgmental*: −.009; *non-reactivity*: −.005).

4.8. Effect of primes on preference judgments

In the preference session, positive primes resulted in marginally faster response times ($F(1,1491) = 2.87$, $p = .090$, see Fig. 5A) and more negative preference judgments ($F(1,1499) = 2.62$, $p = .038$). Negative primes also resulted in significantly faster response times ($F(1,1527) = 6.28$, $p = .012$, see Fig. 4B), and marginally more negative preference judgments ($F(1,1527) = 2.945$, $p = .086$). Neither positive ($F(1,1499) = 2.618$, $p = .106$) nor negative primes ($F(1,1531) = 0.042$, $p = .837$) resulted in an effect on endorsement rate (i.e. in an interaction with grammaticality).

4.9. Effect of primes on grammaticality judgments

In the classification task, positive primes did not result in significant main effects on grammaticality judgments ($F(1,1497) = 1.10$, $p = .158$), endorsement rates ($F(1,1509) = .743$, $p = .389$), or response times ($F(1,1497) = 0.467$, $p = .495$). Negative primes did not result in significant main effects on grammaticality judgments ($F(1,1538) = 1.96$, $p = .162$) or response times ($F(1,1538) = .254$, $p = .615$). However, there was a significant interaction effect between endorsement rates and the grammatical status of the stimulus (GRAMMATICALITY: $F(1,1545) = 4.02$, $p = .045$). As can be seen in Fig. 6, this interaction was the result of negative primes only affecting endorsement of the grammatical sequences.

5. Discussion

5.1. Mindfulness reduces ability to classify grammatical sequences

Mindfulness influenced the endorsement rates in both the preference and grammatical classification task. More mindful individuals displayed less sensitivity to the grammar in their preference judgments. This effect was repeated for judgments of grammaticality. Importantly, mindfulness did not correlate with initial WM performance. Also, after explicitly controlling for differences in initial working memory performance, the effects of mindfulness on endorsement rates remained large and statistically significant. Furthermore, mindfulness did not correlate with the ability to later recall explicit knowledge about the grammar. Together, these findings suggest that while mindfulness impairs both implicit as explicit classification performance, it does not reduce the ability to report bigram knowledge about the grammar or to perform general cognitive operations on similar stimuli. Thus, mindfulness specifically explained individual differences in endorsement of grammatical structures that cannot be explained by general cognitive abilities or the ability to verbally express the implicit knowledge base.

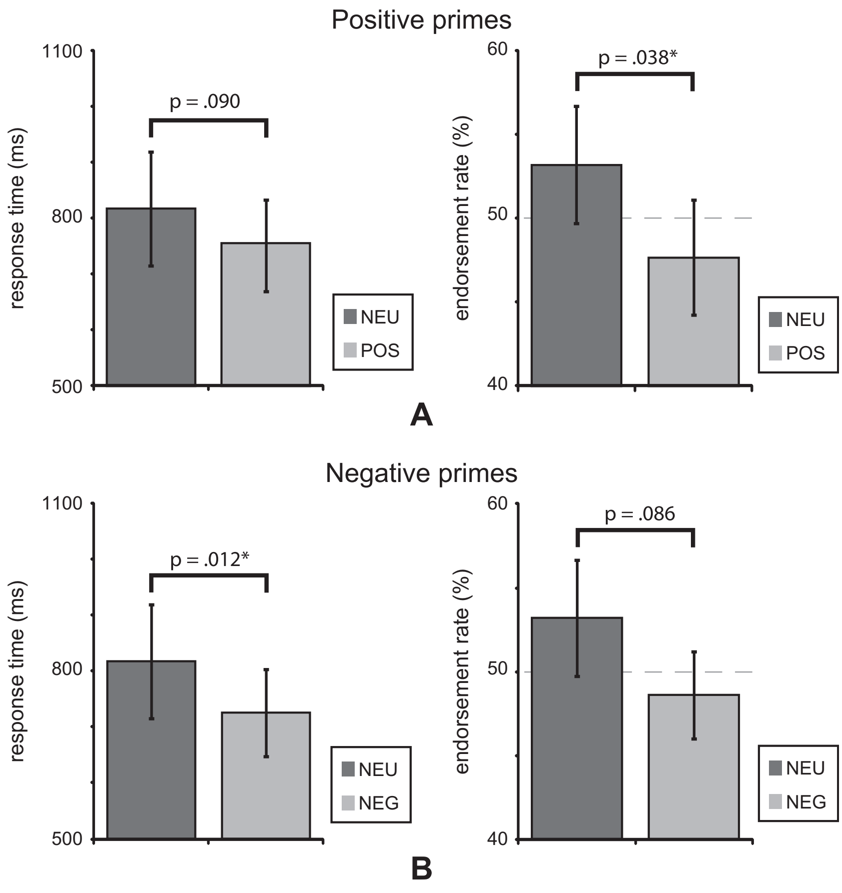

Fig. 5. Positive and negative primes reduce response times and preference ratings. (A) Effect of positive primes on response times and mean endorsement rates on the preference task. (B) Effect of negatives prime on response times and mean endorsement rates on the preference task. *E* denotes that the difference is only significant when EXPLICIT is entered as covariate.

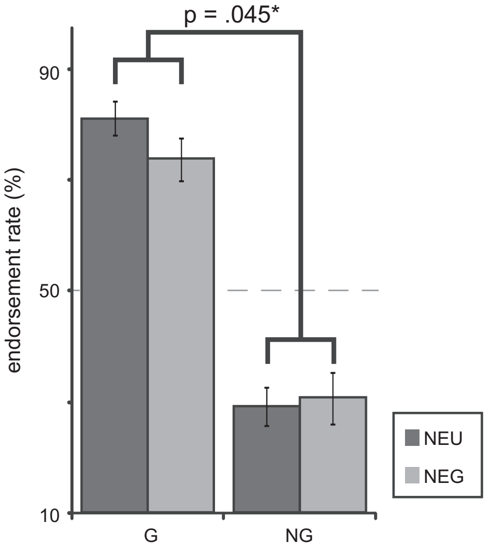

Fig. 6. Interaction effect of negative prime and classification performance depends on explicit knowledge. Endorsement rates after neutral (NEU) and negative (NEG) primes show that grammatical (G) sequences are influenced by negative primes, while non-grammatical (NG) sequences are not.

5.2. Post-hoc investigation of mindfulness subscales

Post-hoc analysis of the separate subscales of the FFMQ further substantiate an explanation of the effects of mindfulness in terms of non-habitual factors. The negative correlation of mindfulness with endorsement rates in the preference task was strongest for the *non-judging of inner experience* subscale. This subscale refers to a non-evaluative stance toward thoughts and feelings (Baer et al., 2008). Within the context of the implicit classification task, preference judgments might have been less biased by internal representation of the grammatical structure. This would be consistent with the claim that mindfulness down-plays a general tendency to automatically judge internal representations (Brown and Ryan (2003) and Bishop et al. (2004)). Interestingly, when participants explicitly judged the grammaticality of the stimuli, the *describe* and *observe* subscale emerged as the most significant predictor of impaired performance. The *describe* subscale refers to the labeling of inner experiences with words. The o*bserving* subscale refers to the noticing or attending to internal and external experiences (Baer et al., 2008). The fact that such dispositions were not beneficial for grammaticality judgments implies that an observing and describing trait inhibits (automatic) acting on internal representations, i.e. using the ‘gut feeling’. This would be in line with findings showing that such classification performance benefits from instructing subjects not to over-analyze the stimuli or their performance (Howard & Howard, 2001). Taken together, these results suggest that implicit knowledge is most reliably accessed by those that rely on habitual responses. Knowledge about the fact that grammatical rules exist (after debriefing) does not change this relationship. Furthermore, a tendency to observe (i.e., to be aware of one’s thoughts, feelings and preferences) might reduce such habitual responses.

5.3. Explicit knowledge and working memory

It is important to note that neither WM performance nor explicit knowledge interacted with endorsement rates in the preference session, but did so significantly after subjects were debriefed. This suggests a qualitative difference between implicit and explicit classification, consistent with the understanding that explicit knowledge about the grammar was used in the explicit classification but not during implicit endorsement rates. Similar findings were reported by Folia et al. (2008) who found that the number of grammatical items that participants were able to generate, predicted endorsement rates for grammaticality classification but not for preference ratings.

Interestingly, while previous work (Kaufman et al., 2010) has shown that working memory capacity is not a major source of variance in AGL performance, WM performance did correlate positively with grammatical classification in our study. However, in contrast to Kaufman et al. (2010) who used an independent task to measure working memory (the Operation Span Task (Turner & Engle, 1989)), our WM task shared both the grammatical structure with classification stimuli as well as the surface features such as the typeface and presentation duration. The WM task should therefore be considered less of a measurement of general WM capacity but rather of a task-specific ability to hold relevant sequences online, specific for our task context. Note that the correlation between WM and explicit knowledge does not imply that WM performance was contaminated by (implicit) understanding of grammar. WM performance in the first session did not correlate significantly with endorsement rates of preference judgments. The last two working memory sessions did show a marginal trend towards significance. However, as participants learned the grammar, that knowledge would have facilitated the remembering of sequences in what constituted the WM task. As such, given that mindfulness appears to limit the learning (or at least the expression of that knowledge) this could have resulted in a negative correlation between WM and the FFMQ score. It should also be noted that the negative relationship between mindfulness and endorsement rates occurred for both the preference and classification task, while working memory performance only showed a correlation with the latter. Further evidence speaking against the possibility that the negative correlation between mindfulness and endorsement rates was mediated through a mutual correlation with (working) memory ability, comes from studies on the relationship between mindfulness and memory. In Jha et al. (2010) and Zeidan, Johnson, Diamond, David, and Goolkasian (2010) mindfulness training was found to *increase* working memory performance. Furthermore, in Williams, Teasdale, Segal, and Soulsby (2000) mindfulness training increased autobiographical memory specificity in recovered depressed patients, which was replicated by Heeren et al. (2009) in healthy subjects. Lastly, working memory performance has been previously shown not to correlate with implicit learning performance (Gebauer and Mackintosh (2007) and Reber et al. (1991). Taken together, we believe it is unlikely that individual differences in WM ability meditated the negative correlation between mindfulness and performance on the grammatical classification and preference task.

5.4. Primes

To test the involvement of affect on the retrieval of implicit knowledge, we preceded stimuli with subliminal affective primes. Preference ratings were found to be faster and preferred less when preceded by a negative prime. Negative primes did not have an effect on endorsement rates. This is consistent with an effect of prime on the response level, but not with an influence on the decision process itself. In fact, while affective primes are classically assumed to automatically activate attitudes towards target stimuli (e.g. Fazio, Sanbonmatsu, Powell, and Kardes (1986) and Forgas (1995)), it has been argued that affective primes also influence decisions regarding the attitude towards the *response*, instead of the stimuli that the response is about (Hermans, De Houwer, & Eelen, 2001). Our findings would be consistent with the latter claim (Hermans et al., 2001).

Unexpectedly, positive primes showed a similar effect as negative primes, both speeding up response times and biasing preference judgments negatively. No interactions with prime valence were observed. A series of studies on the differential effects of the valence of primes used forty-eight and one-hundred-and-sixty participants (Rotteveel et al., 2001). Our study might therefore have suffered from a lack of power. However, a more parsimonious explanation would be that affective primes resulted in a general disruptive effect on the accuracy of implicit decision-making that was independent of prime valence. Our results suggest a general tradeoff between an increased speed of response and a decreased accuracy, after both positive and negative primes.

Interestingly, when participants explicitly rated grammaticality (after debriefing), primes did not have an effect on participants' judgment. As grammaticality judgments took about 200 ms longer than preference ratings, priming effects could by then have dissipated. In fact, priming effects degrade quickly over time, with the maximal effect obtained by a prime-mask SOA from 100 ms to 150 ms, with barely any effects after 300 ms (Hermans et al., 2001; Sohrabi & West, 2009). Alternatively, response times might have been less informative than in preference judgments due to more elaborate conscious decision-making processes.

5.5. Explicit knowledge of bigram transitions

The method by which explicit knowledge of bigrams was measured might offer several improvements over previously used methods. Open questions suffer from a possible lack of sensitivity, due to low confidence, different retrieval contexts or the absence of appropriate words to describe the knowledge base (Destrebecqz & Peigneux, 2005; Shanks & St. John, 1994). On the other hand, forced-choice recognition or sequences-completion tasks, although being more sensitive, suffer from the unavoidable problem that the use of (unconscious) implicit knowledge in their responses cannot be excluded (i.e., the *exclusiveness criterion*, see Reingold and Merikle (1988) and Destrebecqz and Peigneux (2005)). Sampling knowledge of all bi-gram transitions with multiple-choice questions helps participants report bigram knowledge by providing a minimal structure in which the questions are contextualized. By penalizing misses and false alarms response biases can be controlled for. Secondly, the pen-and-paper format provides a different context in which implicit strategies are expected to play less of a role than in setups similar in task context. Note that we only sampled the bi-gram space and higher-order knowledge was not probed. However, given the complexity of higher-order rules, it is unlikely that such knowledge was accessible or used. In fact, none of our subjects reported higher level (tri-gram) rules in the free recall questions of the post-experiment questionnaire.

5.6. Conclusion

To conclude, mindfulness reduced habitual responding to unconsciously acquired preferences, providing experimental evidence for its core concepts: a non-reactive and non-judgmental disposition. Combined with our findings on the influence of affective primes, we show the importance of affective traits and states in implicit learning and retrieval.

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References

Baer, R. A. (2011). Measuring mindfulness. *Contemporary Buddhism, 12*(1), 241–261.
Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*(1), 27–45.
Baer, R. A., Smith, G. T., Lykins, E., Button, D., Krietemeyer, J., Sauer, S., et al (2008). Construct validity of the five facet mindfulness questionnaire in meditating and nonmeditating samples. *Assessment, 15*(3), 329–342.
Bargh, J. A., & Chartrand, T. L. (1999). The unbearable automaticity of being. *American Psychologist, 54*(7), 462–479.
Berridge, K. C., & Winkielman, P. (2003). What is an unconscious emotion? (The case for unconscious ''liking''). *Cognition and Emotion, 17*(2), 181–211.
Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., et al (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice, 11*(3), 230–241.
Bornstein, R. F. (1989). Exposure and affect – overview and meta-analysis of research, 1968–1987. *Psychological Bulletin, 106*(2), 265–289.
Bornstein, R. F., Kale, A. R., & Cornell, K. R. (1990). Boredom as a limiting condition on the mere exposure effect. *Journal of Personality and Social Psychology, 58*(5), 791–800.
Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*(4), 822–848.
Brown, K. W., & Ryan, R. M. (2004). Perils and promise in defining and measuring mindfulness: Observations from experience. *Clinical Psychology – Science and Practice, 11*(3), 242–248.
Brown, K. W., Ryan, R. A., & Creswell, J. D. (2007). Mindfulness: Theoretical foundations and evidence for its salutary effects. *Psychological Inquiry, 18*(4), 211–237.
Carter, S., & Pasqualini, M. C. S. (2004). Stronger autonomic response accompanies better learning: A test of Damasio's somatic marker hypothesis. *Cognition and Emotion, 18*(7), 901–911.
Chiesa, A., & Serretti, A. (2011). Mindfulness based cognitive therapy for psychiatric disorders: A systematic review and meta-analysis. *Psychiatry Research, 187*(3), 441–453.
Cleeremans, A., Destrebecqz, A., & Boyer, M. (1998). Implicit learning: News from the front. *Trends in Cognitive Sciences, 2*(10), 406–416.
Crandall, J. E. (1968). Effects of need for approval and intolerance of ambiguity upon stimulus preference. *Journal of Personality, 36*(1), 67–83.
Damasio, A. R. (2003). *Looking for Spinoza: Joy, sorrow, and the feeling brain* (1st ed.). Orlando, FL: Harcourt.
de Bruin, E. I., Topper, M., Muskens, J. G., Bogels, S. M., & Kamphuis, J. H. (2012). Psychometric properties of the five facets mindfulness questionnaire (FFMQ) in a meditating and a non-meditating sample. *Assessment, 19*(2), 187–197.
de Vries, M. H., Barth, A. C., Maiworm, S., Knecht, S., Zwitserlood, P., & Floel, A. (2010). Electrical stimulation of Broca's area enhances implicit learning of an artificial grammar. *Journal of Cognitive Neuroscience, 22*(11), 2427–2436.
Destrebecqz, A., & Peigneux, P. (2005). Methods for studying unconscious learning. *Progress in Brain Research, 150*, 69–80.
Fazio, R. H., Sanbonmatsu, D. M., Powell, M. C., & Kardes, F. R. (1986). On the automatic activation of attitudes. *Journal of Personality and Social Psychology, 50*(2), 229–238.
Folia, V., Udden, J., Forkstam, C., Ingvar, M., Hagoort, P., & Petersson, K. M. (2008). Implicit learning and dyslexia. *Learning, Skill Acquisition, Reading, and Dyslexia, 1145*, 132–150.
Forgas, J. P. (1995). Mood and judgment: The affect infusion model (AIM). *Psychological Bulletin, 117*(1), 39–66.
Forkstam, C., Elwer, A., Ingvar, M., & Petersson, K. M. (2008a). Instruction effects in implicit artificial grammar learning: A preference for grammaticality. *Brain Research, 1221*, 80–92.
Forkstam, C., Elwér, Å., Ingvar, M., & Petersson, K. M. (2008b). Instruction effects in implicit artificial grammar learning: A preference for grammaticality. *Brain Research, 1221*, 80–92.
Forkstam, C., Hagoort, P., Fernandez, G., Ingvar, M., & Petersson, K. M. (2006). Neural correlates of artificial syntactic structure classification. *NeuroImage, 32*, 956–967.
Forkstam, C., & Petersson, K. M. (2005a). Syntactic classification of acquired structural regularities. *Proceedings of Cognitive Science Society*, 696–701.
Forkstam, C., & Petersson, K. M. (2005b). Towards an explicit account of implicit learning. *Current Opinion in Neurology, 18*(4), 435–441.
Frijda, N. H. (1986). *The emotions*. Cambridge: Cambridge University Press.
Gebauer, G. F., & Mackintosh, N. J. (2007). Psychometric intelligence dissociates implicit and explicit learning. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 33*(1), 34–54.
Gordon, P. C., & Holyoak, K. J. (1983). Implicit learning and generalization of the mere exposure effect. *Journal of Personality and Social Psychology, 45*(3), 492–500.
Greenberg, J., Reiner, K., & Meiran, N. (2012). ''Mind the Trap'': Mindfulness practice reduces cognitive rigidity. *PLoS ONE, 7*(5), e36206.
Grossman, P., & Van Dam, N. T. (2011). Mindfulness, by any other name...: Trials and tribulations of sati in western psychology and science. *Contemporary Buddhism, 12*(1), 219–239.
Harmon-Jones, E., & Allen, J. J. B. (2001). The role of affect in the mere exposure effect: Evidence from psychophysiological and individual differences approaches. *Personality and Social Psychology Bulletin, 27*(7), 889–898.
Heeren, A., Van Broeck, N., & Philippot, P. (2009). The effects of mindfulness on executive processes and autobiographical memory specificity. *Behaviour Research and Therapy, 47*(5), 403–409.
Hermans, D., De Houwer, J., & Eelen, P. (2001). A time course analysis of the affective priming effect. *Cognition and Emotion, 15*(2), 143–165.
Hodgins, H. S., & Adair, K. C. (2010). Attentional processes and meditation. *Consciousness and Cognition, 19*(4), 872–878.
Howard, D. V., & Howard, J. H. (2001). When it does hurt to try: Adult age differences in the effects of instructions on implicit pattern learning. *Psychonomic Bulletin & Review, 8*(4), 798–805.
Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective & Behavioral Neuroscience, 7*(2), 109–119.
Jha, A. P., Stanley, E. A., Kiyonaga, A., Wong, L., & Gelfand, L. (2010). Examining the protective effects of mindfulness training on working memory capacity and affective experience. *Emotion, 10*(1), 54–64.
Kabat-Zinn, J. (1994). *Wherever you go, there you are: Mindfulness meditation in everyday life* (1st ed.). New York: Hyperion.
Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology – Science and Practice, 10*(2), 144–156.

Kaufman, S. B., De Young, C. G., Gray, J. R., Jimenez, L., Brown, J., & Mackintosh, N. (2010). Implicit learning as an ability. *Cognition, 116*(3), 321–340.
Kingston, T., Dooley, B., Bates, A., Lawlor, E., & Malone, K. (2007). Mindfulness-based cognitive therapy for residual depressive symptoms. *Psychology and Psychotherapy – Theory Research and Practice, 80*, 193–203.
Knowlton, B. J., & Squire, L. R. (1996). Artificial grammar learning depends on implicit acquisition of both abstract and exemplar-specific information. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 22*(1), 169–181.
Kouider, S., & Dehaene, S. (2007). Levels of processing during non-conscious perception: A critical review of visual masking. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 362*(1481), 857–875.
Kuhlman, J. R. (2002). One dharma: The emerging western Buddhism. *Library Journal, 127*(13), 103–104.
Lieberman, M. D., Chang, G. Y., Chiao, J., Bookheimer, S. Y., & Knowlton, B. J. (2004). An event-related fMRI study of artificial grammar learning in a balanced chunk strength design. *Journal of Cognitive Neuroscience, 16*, 427–438.
Lundqvist, D., Flykt, A., & Ohman, A. (1998). *Karolinska directed emotional faces*. Stockholm: D.o.C.N. Psychology Section, Karolinska Hospital.
Lutz, A., Slagter, H. A., Rawlings, N. B., Francis, A. D., Greischar, L. L., & Davidson, R. J. (2009). Mental training enhances attentional stability: Neural and behavioral evidence. *Journal of Neuroscience, 29*(42), 13418–13427.
Meulemans, T., & Van der Linden, M. (1997). Associative chunk strength in artificial grammar learning. *Journal of Experimental Psychology – Learning Memory and Cognition, 23*(4), 1007–1028.
Moore, A., & Malinowski, P. (2009). Meditation, mindfulness and cognitive flexibility. *Consciousness and Cognition, 18*(1), 176–186.
Newell, B. R., & Bright, J. E. (2001). The relationship between the structural mere exposure effect and the implicit learning process. *Quarterly Journal of Experimental Psychology. A, Human Experimental Psychology, 54*(4), 1087–1104.
Norman, E., Price, M. C., & Duff, S. C. (2006). Fringe consciousness in sequence learning: The influence of individual differences. *Consciousness and Cognition, 15*(4), 723–760.
Norman, E., Price, M. C., Duff, S. C., & Mentzoni, R. A. (2007). Gradations of awareness in a modified sequence learning task. *Consciousness and Cognition, 16*(4), 809–837.
Oosterhof, N. N., & Todorov, A. (2008). The functional basis of face evaluation. *Proceedings of the National academy of Sciences of the United States of America, 105*(32), 11087–11092.
Petersson, K. M., Folia, V., & Hagoort, P. (2010). What artificial grammar learning reveals about the neurobiology of syntax. *Brain and Language*. http://dx.doi.org/10.1016/j.bandl.2010.08.003.
Piet, J., & Hougaard, E. (2011). The effect of mindfulness-based cognitive therapy for prevention of relapse in recurrent major depressive disorder: A systematic review and meta-analysis. *Clinical Psychology Review, 31*(6), 1032–1040.
Proulx, T., & Heine, S. J. (2009). Connections from Kafka: Exposure to meaning threats improves implicit learning of an artificial grammar. *Psychological Science, 20*(9), 1125–1131.
Raes, F., Dewulf, D., Van Heeringen, C., & Williams, J. M. (2009). Mindfulness and reduced cognitive reactivity to sad mood: Evidence from a correlational study and a non-randomized waiting list controlled study. *Behaviour Research and Therapy, 47*(7), 623–627.
Ramel, W., Goldin, P. R., Carmona, P. E., & McQuaid, J. R. (2004). The effects of mindfulness meditation on cognitive processes and affect in patients with past depression. *Cognitive Therapy and Research, 28*(4), 433–455.
Reber, A. S., Walkenfeld, F. F., & Hernstadt, R. (1991). Implicit and explicit learning: Individual differences and IQ. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 17*(5), 888–896.
Reingold, E. M., & Merikle, P. M. (1988). Using direct and indirect measures to study perception without awareness. *Percept Psychophys, 44*(6), 563–575.
Roemer, L., & Orsillo, S. M. (2002). Expanding our conceptualization of and treatment for generalized anxiety disorder: Integrating mindfulness/acceptance-based approaches with existing cognitive-behavioral models. *Clinical Psychology – Science and Practice, 9*(1), 54–68.
Rose, M., Haider, H., Weiller, C., & Buchel, C. (2002). The role of medial temporal lobe structures in implicit learning: An event-related FMRI study. *Neuron, 36*, 1221–1231.
Rotteveel, M., de Groot, P., Geutskens, A., & Phaf, R. H. (2001). Stronger suboptimal than optimal affective priming? *Emotion, 1*(4), 348–364.
Schmitt, W. A., Brinkley, C. A., & Newman, J. P. (1999). Testing Damasio's somatic marker hypothesis with psychopathic individuals: Risk takers or risk averse? *Journal of Abnormal Psychology, 108*(3), 538–543.
Scott, R. B., & Dienes, Z. (2010). Fluency does not express implicit knowledge of artificial grammars. *Cognition, 114*(3), 372–388.
Segal, Z. V., Williams, J. M. G., & Teasdale, J. D. (2002). *Mindfulness-based cognitive therapy for depression: A new approach to preventing relapse*. New York: Guilford Press.
Seger, C. A. (1994). Implicit learning. *Psychological Bulletin, 115*(2), 163–196.
Shanks, D. R., & St. John, M. F. (1994). Characteristics of dissociable human learning-systems. *Behavioral and Brain Sciences, 17*(3), 367–395.
Slagter, H. A., Lutz, A., Greischar, L. L., Francis, A. D., Nieuwenhuis, S., Davis, J. M., et al (2007). Mental training affects distribution of limited brain resources. *PLoS Biology, 5*(6), e138.
Sohrabi, A., & West, R. L. (2009). Positive and negative congruency effects in masked priming: A neuro-computational model based on representation, attention, and conflict. *Brain Research, 1289*, 124–132.
Stadler, M. A., & Frensch, P. A. (1998). *Handbook of implicit learning*. Thousand Oaks: Sage Publications.
Teasdale, J. D., Moore, R. G., Hayhurst, H., Pope, M., Williams, S., & Segal, Z. V. (2002). Metacognitive awareness and prevention of relapse in depression: Empirical evidence. *Journal of Consulting and Clinical Psychology, 70*(2), 275–287.
Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent. *Journal of Memory and Language, 28*(2), 127–154.
Udden, J., Folia, V., Forkstam, C., Ingvar, M., Fernandez, G., Overeem, S., et al (2008). The inferior frontal cortex in artificial syntax processing: An rTMS study. *Brain Research, 1224*, 69–78.
van den Bussche, E., van den Noortgate, W., & Reynvoet, B. (2009). Mechanisms of masked priming: A meta-analysis. *Psychological Bulletin, 135*(3), 452–477.
van den Hurk, P. A., Giommi, F., Gielen, S. C., Speckens, A. E., & Barendregt, H. P. (2010). Greater efficiency in attentional processing related to mindfulness meditation. *The Quarterly Journal of Experimental Psychology (Hove), 63*(6), 1168–1180.
Veehof, M. M., Ten Klooster, P. M., Taal, E., Westerhof, G. J., & Bohlmeijer, E. T. (2011). Psychometric properties of the Dutch five facet mindfulness questionnaire (FFMQ) in patients with fibromyalgia. *Clinical Rheumatology, 30*(8), 1045–1054.
Williams, J. M., Teasdale, J. D., Segal, Z. V., & Soulsby, J. (2000). Mindfulness-based cognitive therapy reduces overgeneral autobiographical memory in formerly depressed patients. *Journal of Abnormal Psychology, 109*(1), 150–155.
Yin, H. H., & Knowlton, B. J. (2006). The role of the basal ganglia in habit formation. *Nature Reviews Neuroscience, 7*, 464–476.
Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9*(2p2). 1.
Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition, 19*(2), 597–605.
Zizak, D. M., & Reber, A. S. (2004). Implicit preferences: The role(s) of familiarity in the structural mere exposure effect. *Consciousness and Cognition, 13*(2), 336–362.
Zylowska, L., Ackerman, D. L., Yang, M. H., Futrell, J. L., Horton, N. L., Hale, T. S., et al (2008). Mindfulness meditation training in adults and adolescents with ADHD: A feasibility study. *Journal of Attention Disorders, 11*(6), 737–746.