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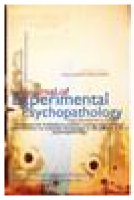

Automatization and familiarity in repeated checking: A replication

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Abstract

Repetitive, compulsive-like checking of an object leads to reductions in memory confidence, vividness, and detail. Experimental research suggests that this is caused by increased familiarity with perceptual characteristics of the stimulus and automatization of the checking procedure (Dek, van den Hout, Giele, & Engelhard, 2014). This suggests that defamiliarization by modifying perceptual characteristics of the stimulus will result in de-automatization and attenuation of the meta-memory effects. However, this was not found (Dek et al., 2014), but the manipulation may have been too weak.

In two experiments, the present investigation examined whether modification of the defamiliarization procedure (i.e., enlarging the amount of color alterations of the stimuli) would result in de-automatization and attenuation of the meta-memory effects. Undergraduates performed a checking task, in which they activated, de-activated, and checked stimuli. Meta-memory was rated after a pre- and post-test checking trial. Simultaneously, automatization of checking was measured with a reaction time task during the pre- and post-test checking trial. In the reaction time task participants responded as quickly as possible to tones. In both experiments, perseverative checking reduced memory confidence, vividness, and detail, and led to automatization of checking behavior. In Experiment I, moderate defamiliarization led to de-automatization, but did not attenuate meta-memory effects of checking. In Experiment II, strong defamiliarization did not lead to de-automatization, but did reduce the detrimental effects of re-checking on memory confidence and vividness. This research suggests that automatization is a potential mechanism underlying the paradoxical phenomenon of perseveration leading to memory uncertainty.

Keywords: Repeated checking; Memory uncertainty; Familiarity; Automatization; Defamiliarization; Obsessive-compulsive disorder

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Introduction

Ironic effects of perseveration

The majority of patients with OCD engage in perseverative behavior, such as checking, extensive washing, or cleaning, to reduce feelings of uncertainty (Ruscio, Stein, Chiu, & Kessler, 2010; Tallis, 1995). However, many studies have revealed that perseverative checking does not reduce uncertainty, but, paradoxically, increases it. The first experiments that demonstrated this phenomenon were conducted by Van den Hout and Kindt (2003a; 2003b; 2004). Participants engaged in perseverative checking in a computer task: they repeatedly activated virtual gas burners or light bulbs, deactivated them, and checked whether they had been accurately deactivated. Before and after 20 checking trials, participants rated their memory confidence, vividness and detail. In between these tests, a ‘relevant checking’ condition performed 20 checks on the same stimuli, and an ‘irrelevant checking’ (control) condition checked different stimuli. Results indicated that repeated relevant checking reduced memory confidence, vividness and detail, but did not affect memory accuracy. These ironic effects occur with a relatively low number of checks (Coles, Radomsky, & Horng, 2006), and have been replicated with real-life stimuli (Radomsky, Gilchrist, & Dussault, 2006), in patients with OCD (Boschen & Vuksanovic, 2007), with mental instead of physical checking (Radomsky & Alcolado, 2010), and with abstract, threat irrelevant stimuli (Dek, van den Hout, Giele, & Engelhard, 2010).

Explanation of ironic effects: familiarity and automatization

Van den Hout and Kindt (2003a) suggested that the mechanism underlying this phenomenon may be a switch from perceptual to conceptual processing. Basic research has shown that increased familiarity with stimuli inhibits the processing of perceptual elements, thereby decreasing vividness and detail of recollections (Johnston & Hawley, 1994; Roediger, 1990). Van den Hout and Kindt proposed that a similar process may occur in repetitive, compulsive checking, and that this reduction in vividness and detail subsequently undermines memory confidence. Dek et al. (2014) tested whether checking behavior indeed automatizes as a result of familiarity and practice (i.e., repeated checking of the same stimuli). An ‘automatic’ checking routine should be executed more efficiently, and leave more cognitive capacity available for other concurrent tasks. Dek et al. (2014) studied whether perseverative checking leads to automatization, and also tested whether defamiliarization of stimuli reduces automaticity.

To investigate automatization in repeated checking, Dek et al. (2014) focused on efficiency, which is a characteristic of automaticity (Bargh, 1994; see Moors & de Houwer, 2006), and is usually described as “the extent to which the perceptual or judgment process demands attentional resources” (Bargh, 1994, p. 24). An effective way to study efficiency is by the use of a dual-task paradigm, in which participants perform a primary task while simultaneously performing a second task that requires attentional resources (McNally, 1995; Teachman, Joormann, Steinman, & Gotlieb, 2012). Accordingly, Dek and colleagues (2014) extended the checking task by Van den Hout and Kindt (2003a) with a reaction time (RT) task. That is, during the pre- and post-test of the checking task, participants were instructed to check virtual stimuli, and *simultaneously* respond to a tone that was repeatedly presented. Reaction times and the duration of checking procedures were used to assess efficiency, because this combination provides an indication of the demand on attentional resources. Automatization was operationalized as more efficient (faster) performance on the checking task and RT task.

Many earlier studies used an ‘irrelevant checking’ control condition, in which paradoxical effects of checking were not found. This suggests that mere repetition is not responsible for the paradoxical effects of checking. However, these studies did not indicate whether automatization contributes to the paradoxical effects. As an additional test of the automatization hypothesis of perseverative checking, Dek and colleagues (2014) proposed that defamiliarization of the checked items, by using novel colors, would lead to de-automatization of the checking routine. In order to test this hypothesis, they added a ‘relevant checking’ condition with defamiliarization. Stimulus familiarization is reached by prolonged contact with that specific stimulus (i.e., stimulus characteristics, such as color and shape, remain consistent). In contrast, defamiliarization is defined as making a familiar stimulus less familiar by modifying its perceptual characteristics. It was operationalized as an unexpected change of the (context) color of the stimuli. Whereas automatization is thought to occur in a continuous gradual fashion over the course of repetition (e.g., Moors & de Houwer, 2006), we presume that de-automatization can be reached with a single modification. De-automatization is indicated by an increase of required attentional resources (i.e., less efficient performance), and was operationalized as slower performance on the checking task and RT task. De-automatization does not imply that the process is no longer automatic at all, but that it has made a leap backwards on the automaticity continuum. Dek et al. (2014) also predicted that defamiliarization and de-automatization would make the recollection of the check more distinct and would attenuate the negative meta-memory effects caused by repeated checking.

Data on familiarity and automatization

Dek et al. (2014), indeed, found that repeated relevant checking, compared to irrelevant checking, led to faster checking at the post-test, but not to faster performance on the RT task. Dek and colleagues concluded that the faster checking suggests that repeated checking did lead to automatization, although the predicted larger drop in RTs in the experimental relevant checking condition was not observed.

Data on defamiliarization and de-automatization

A small study about perseverative checking has reported positive effects of perceptual interference on memory. Tallis (1993) made checks for three patients with OCD more memorable by using a doubt reduction procedure. It was used as an incentive to engage in exposure and response prevention therapy, which otherwise was considered to be too demanding. In this procedure, a successful check was made more memorable by associating it with a novel, distinctive stimulus. Participants looked at colored figures after performing a successful check, and were instructed to form a mental image of this stimulus as a reminder of the successful check. As a result of this doubt reduction procedure, doubt ratings and repeated checking behavior reduced.

Dek and colleagues (2014) added an experimental condition to the original checking task to induce perceptual defamiliarization. This 'relevant checking' with defamiliarization condition was identical to the 'relevant checking' without defamiliarization condition, except for the post-test, in which the color of the background of the stimuli unexpectedly altered from dark grey into bright blue. Contrary to the hypotheses, the defamiliarization condition, compared to the other conditions, showed similar reductions in check duration and an even larger reduction in RTs at the post-test. Furthermore, defamiliarization did not diminish the negative meta-memory effects caused by repeated checking. A possible explanation for these unexpected results is that the use of color as a 'defamiliarizer' was insufficient. Lassaline and Logan (1993) studied the influence of stimulus alterations on memory retrieval in a counting task. They found no evidence that modifying stimulus identity (changing letters) or color (changing red asterisks into green) led to de-automatization of memory retrieval (i.e., slower task performance). Only when the orientation of learned visual patterns was changed (rotating patterns 180°), de-automatization occurred, which was depicted by slower task performance. Lassaline and Logan suggested that color alterations may actually make a pattern more memorable. Therefore, it is possible that the color modification in the study by Dek et al. was insufficient to induce de-automatization. Moreover, the object and amount of color alterations may also play a crucial role in the induction of de-automatization. This is essentially the argument advanced by Dek and colleagues (2014), and is supported by a study by Boschen, Wilson and Farrell (2011).

Boschen and colleagues (2011) also studied the effect of stimulus modification. They demonstrated that the perceptual modification of stimuli during checking attenuated the negative effects of repeated checking on memory confidence, vividness and detail. Whereas Dek et al. only altered the context color at the post-test, Boschen and colleagues modified the color of the stimuli after every five checks. They concluded that the color alterations led to a shift from conceptual to perceptual processing at the post-test, which reduced memory distrust. These results are promising, and suggest that color modification may be a way to induce defamiliarization and de-automatization. However, it is unclear whether the design of the Boschen et al. study actually allowed for de-automatization. The stimuli modification every five checks may have prevented automatization to take place (i.e., a shift from perceptual to conceptual processing). Therefore, we decided not to potentially disrupt this automatization process by 'premature' defamiliarization, and to induce defamiliarization only at the post-test. Furthermore, in light of the generalizability to a clinical setting, testing the effects of defamiliarization after a longer series of checks seems to make sense as well: in real-life, the stimuli that are subject to perseverative behavior in patients with OCD usually do not differ frequently (e.g., they check the same stove, the same water tap, the same locks).

Dek and colleagues (2014) suggested that their operationalization of defamiliarization (i.e., modifying the context color of the stimuli instead of stimuli color) was not distinct enough. Context can play an important role in memory retrieval (Chun & Jiang, 1998; Lockhart & Craik, 1990), familiarity of the background can improve performance (Karni & Sagi, 1991), and recognition of the context can start off an automatic routine (Shiffrin & Schneider, 1977). However, the alteration of solely the context color as a means to induce defamiliarization may have been insufficient, and hence, could not induce de-automatization and reduce the meta-memory effects of repeated checking. A previous study on the effects of contextual relevance in repetitive checking supports this notion. Ashbaugh and Radomsky (2007) tried to attenuate the negative effects of repeated checking on meta-memory by shifting attentional focus between the stimulus (i.e., gas stove) and the context (i.e., kitchen) during checking. Results indicated that although memory accuracy increased in the contextual focus condition, the shift in attentional focus did not lead to attenuation of the reductions in memory confidence, vividness and detail.

Present study

The first aim of the current investigation was to replicate the Dek et al. (2014) study to be able to make more definite statements about automatization as an underlying mechanism in perseverative checking. The defamiliarization procedure was improved by changing the color of the stimuli and knobs instead of the background color. We decided to alter the color of the knobs as well, because during the execution of the checking procedure participants not only fixate on the circles but also on the turning knobs. We predicted that (1) repeated relevant checking leads to reductions in memory confidence, vividness and detail, without affecting memory accuracy; (2) the relevant checking condition, compared to the irrelevant checking condition becomes faster in executing the checking procedures and on a secondary RT task (reflecting automatization); (3) defamiliarization leads to de-automatization on the checking task (longer check durations) and the RT task (slower RTs); and (4) defamiliarization attenuates the negative meta-memory effects of repeated checking.

Experiment I

Method

Participants

A total of 113 students from Utrecht University and Utrecht University of Applied Sciences enrolled in this study. Color blindness was an exclusion criterion. Prior to the statistical analyses, eight participants were removed from the analyses because of incomplete data (n = 3), detailed prior knowledge about the task (n = 1), or not following task instructions (n = 1). We asked participants whether they were suffering from psychological problems, and excluded those who reported they did. This led to removing three participants with self-reported psychopathology (e.g., a diagnosis of ADD, ADHD, MDD). As a result, 105 participants (69 females, 36 males) remained. They were, on average, 21.8 (SD = 2.3) years old, and were given a small remuneration or course credit for their participation.

Procedure and computer task

Participants were asked to perform a computer task, during which they completed questionnaires. They sat in front of a computer screen in a sound-attenuated and dimly lit laboratory room. We used a modified version of the checking task/reaction time task combination and procedure used by Dek et al. (2014). The computer task consisted of two partially simultaneously administered tasks, and took approximately 20 minutes.

Computer task, part I: Checking task

The original checking task by van den Hout and Kindt (2003a) was modified following Dek and colleagues (2010), by using abstract stimuli. We used six large circles with a star in it, or six small grey circles, and six corresponding turning knobs, which were all presented on a dark grey background (see Figure 1). The color combination of the six large circles + stars and corresponding six turning knobs was either green circles + red stars and grey knobs, or black circles + white stars and blue knobs, respectively. The checking task started with a training phase, in which participants were trained to activate and deactivate the stimuli by moving the corresponding virtual turning knobs with the computer mouse. Half of the participants practiced with the green circles + red stars and grey turning knobs, and the other half practiced with the black circles + white stars and blue turning knobs. All participants also practiced with the small grey circles. In the pre-test that followed, a schematic figure of the six circles was shown, in which three circles were marked. Participants were instructed to activate and deactivate these three circles in the following screens, and to then check whether they had deactivated the circles accurately. Then, participants were instructed to fill out a questionnaire using Visual Analogue Scales (VASs) about this checking trial (see: Assessments). Check duration of the pre-test checking trial (i.e., activating, deactivating and checking for accurate deactivation) was recorded by the computer. After the pre-test, participants were asked to complete another 15 checking trials, in which they had to activate, deactivate, and check random selections of three out of six circles. After these 15 checking trials, the post-test was unexpectedly administered. In this test, participants completed one more checking trial and filled out the questionnaire about this last checking trial.

Participants were randomly assigned to one of three conditions. All conditions were presented the large circles + stars at pre- and post-test (administration of the green circles + red stars and grey turning knobs, or the black circles + white stars and blue turning knobs was counterbalanced across participants). Figure 1 shows a schematic illustration of the three conditions. In the *relevant checking without defamiliarization condition (R-)*, the same stimuli were used during the 15 checking trials that were presented during the pre- and post-test. In the *irrelevant checking condition (IR)*, different stimuli were used between the pre- and post-test (i.e., the large green circles + red stars and grey knobs at the pre- and post-test, but small grey circles during the 15 checking trials, or the large black circles + white stars at the pre- and post-test, but small grey circles during the 15 checking trials). In the *relevant checking with defamiliarization condition (R+)*, the same stimuli were shown during the 15 checking trials that were presented during the pre- and post-test, but at the post-test, the color of stimuli was altered from green circles + red stars and grey knobs into black circles + white stars and blue knobs (or vice versa, this was counterbalanced across participants).

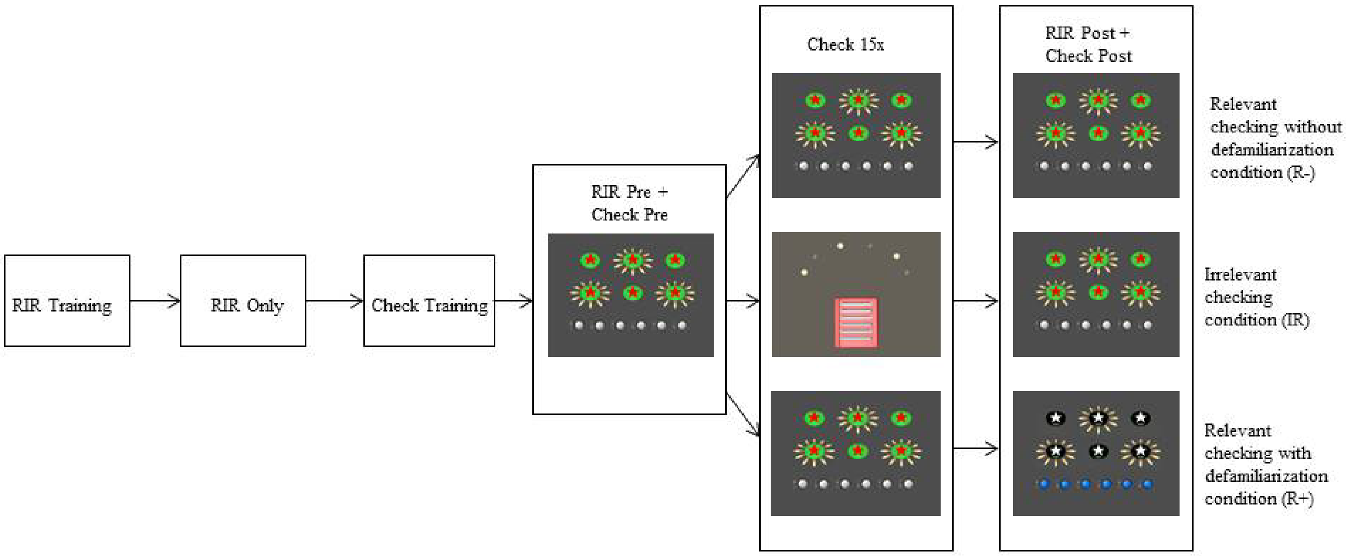

Figure 1: Schematic overview of task administration over time for the different phases of the Rapid Interval Repetition (RIR) task and the checking task (Check) in Experiment I.

Computer task, part II: Rapid Interval Repetition (RIR) task

The RIR task and procedure were similar to the task that was used by Dek et al. (2014). They used a RIR task (Vandierendonck, de Voogt, & van der Goten, 1998) as a secondary reaction time task. In this RT task, auditory stimuli were presented at a tone pitch of 250 Hz and with a maximum duration of 200 ms, with random intervals ranging between 2.5 and 5 s. Participants had to respond as fast and accurately as possible when they heard a beep, by pressing a knob on the response box with the index finger of their non-dominant hand. The RT task started with a training phase (20 s), and the RIR Only baseline measure (60 s). Next, participants were instructed to keep their finger on the response box during the entire experiment, as the beeps could re-appear any moment. However, the beeps only re-appeared on two occasions: during the pre- and post-test of the checking task. The RIR task consisted of three measurement phases: RIR Only, RIR Pre and RIR Post.

Computer task, part III: Checking task and RIR task Combined

During the pre-test and post-test of the checking task, a checking trial and the RT task were simultaneously administered (see Figure 1).

Assessments

Memory accuracy at pre-test and post-test was assessed by asking participants to mark which three out of six circles they had to check during the last checking trial on a paper representation of the six circles.

Memory confidence was assessed by asking participants to rate how confident they were that their answer on the accuracy question was correct on a 100 mm VAS (0 = absolutely not confident, 100 = absolutely confident).

Vividness and *detail* of the last check were rated on two separate VASs (0 = not vivid, 100 = extremely vivid; 0 = not detailed, 100 = extremely detailed).

Data modification

Checking task

Data from one participant (IR condition) was excluded from the analyses, because the mean check duration exceeded *M* + 3 *SD* from the group mean.

Rapid Interval Repetition (RIR) task

Mean reaction times (RTs) were calculated for each participant for each of the RIR phases (RIR Only, RIR Pre and RIR Post). Because the administration of the beeps at RIR Pre and RIR Post was relatively unexpected (e.g., a long period had passed without presentation of the auditory stimuli), the first RT on both RIR Pre and RIR Post were excluded. Furthermore, RTs faster than 100 ms were excluded, because mean auditory reaction times to auditory stimuli are generally accepted to be approximately 140 ms (Brebner & Welford, 1980). Extreme RTs were calculated for each phase and each condition separately, to allow for task differences and potential group differences on the different phases of the RIR. Responses with latencies exceeding 3 SD from the original means were considered to be outliers and were excluded from the analyses. New means were calculated for each RIR phase and each condition separately.

Statistical analyses

The Pearson correlations between the memory ratings at the pre-test (memory confidence and vividness, $r = .51$; memory confidence and detail, $r = .48$; vividness and detail, $r = .78$, all *p*s <.001) were moderate, which suggested appropriateness of MANOVA (Tabachnick & Fidell, 2007). Therefore, to examine the effects of repeated checking on memory confidence, vividness and detail, a 2 (Time: pre-test, post-test) x 3 (Condition: R-, IR, R+) repeated measures (RM) MANOVA was conducted. The RM MANOVA was followed by univariate analyses, and simple main effects analyses were appropriate. Because check duration at pre-test and RIR Pre did not significantly correlate ($r = -.09$, $p = .39$), two separate RM ANOVAs were conducted to test the effect of repeated checking on check duration and RT. Hypotheses were tested using planned comparisons ($\alpha = .05$), that examined whether differences in dependent variable ratings between R- vs. IR, and R- vs. R+, were significant. To control for type I error rates for multiple comparisons, the Bonferroni correction was applied to the post hoc comparisons on IR vs. R+, which resulted in testing at a .025 (.05/2) alpha level.

Results

Experimental conditions

One hundred-and-four participants were included in the analyses ($n = 37$ in R-, $n = 33$ in IR, and $n = 34$ in R+). Conditions were similar regarding age, $F(2,101) = 0.13$, $p = .88$, and gender, $\chi^2(2, N = 104) = 4.19$, $p = .12$.

Memory accuracy

Findings in Table 1 suggest that after repeated checking, there were no differences in memory accuracy between the conditions. The 2 (Time: pre-test, post-test) x 3 (Condition: R-, IR, R+) RM ANOVA did not show significant main effects or interaction effect, *F*s < 2.1.

Table 1: Means and Standard Deviations of Memory Accuracy, and Memory Confidence, Vividness and Detail Ratings Before and After Repeated Checking in Experiment I

	Pre-test	Post-test
Memory accuracy		
R-	2.81 (.70)	2.51 (.90)
IR	2.82 (.64)	2.94 (.24)
R+	2.59 (1.02)	2.74 (.62)
Memory confidence		
R-	77.89 (24.61)	56.03 (25.1)
IR	81.70 (26.08)	77.73 (27.48)
R+	79.38 (26.67)	50.29 (29.49)
Vividness		
R-	68.11 (26.05)	49.43 (24.87)
IR	68.82 (26.45)	66.91 (29.22)
R+	71.03 (24.66)	48.00 (30.07)
Detail		
R-	60.78 (25.53)	43.92 (28.82)
IR	67.15 (24.96)	64.91 (25.65)
R+	65.00 (21.56)	40.32 (30.19)

Note. R- = relevant checking without defamiliarization condition (n = 37), IR = irrelevant checking condition (n = 33), R+ = relevant checking with defamiliarization condition (n = 34).

Memory confidence, vividness and detail

Results from the RM MANOVA with memory confidence, vividness and detail as dependent variables indicated a significant Time x Condition interaction, F (6,200) = 2.28, p <.05, η_p^2 = .06. To assess the effect of repeated checking on *memory confidence*, a 2 x 3 mixed ANOVA with Time (pre-test, post-test) as within-groups variable and Condition (R-, IR, R+) as between-groups variable was performed. Results showed significant main effects of Time, F (1,101) = 32.33, p <. 001, η_p^2 = .24, and Condition, F (2,101) = 4.98, p < .01, η_p^2 = .09, which were qualified by a Time x Condition interaction, F (2,101) = 5.21, p < .01, η_p^2 = .09. After repeated checking, confidence in memory declined in the relevant checking without defamiliarization condition (R-), F (1,101) = 16.44, p <.001, η_p^2 = .14, and the relevant checking with defamiliarization condition (R+), F (1,101) = 26.74, p <.001, η_p^2 = .21, while there was no reduction in memory confidence for the irrelevant checking condition (IR), F (1,101) < 1, p = .49. The reduction in memory confidence for R- differed from IR, t (68) = 2.19, p < .05, d = .52, while the reduction for R+ did not differ from R-, t (69) = .93, p = .36.

The RM ANOVA on *vividness of memory* showed a significant main effect of Time, F (1,101) = 27.51, p <. 001, η_p^2 = .21, which was qualified by a Time x Condition interaction, F (2,101) = 5.23, p < .01, η_p^2 = .09. Vividness of memory significantly declined for R-, F (1,101) = 16.19, p <.001, η_p^2 = .14, and R+, F (1,101) = 22.62, p <.001, η_p^2 = .18, but not for IR, F (1,101) = .15, p = .70. The reduction in vividness for R- differed from IR, t (68) = 2.39, p < .05, d = .57, while the reduction for R+ did not differ from R-, t (69) = .67, p = .51.

The mixed ANOVA on *detail* showed main effects of Time, F (1,101) = 27.95, p < .001, η_p^2 = .22, and Condition, F (2,101) = 4.17, p < .05, η_p^2 = .08, which were qualified by a Time x Condition interaction, F (2,101) = 5.49, p < .01, η_p^2 = .10. Detail of memory declined for R-, F (1,101) = 13.31, p <.001, η_p^2 = .12, and R+, F (1,101) = 26.18, p <.001, η_p^2 = .21, but not for IR, F (1,101) = .21, p = .65. The decline in detail of memory for R- differed from IR, t (68) = 2.09, p < .05, d = .50, while the decline for R+ did not differ from R-, t (69) = 1.11, p = .27.

In line with our first hypothesis, repeated relevant checking while performing a secondary RT task led to reductions in memory confidence, vividness, and detail, but memory accuracy remained unaffected. Contrary to our fourth hypothesis, defamiliarization did not reduce the negative (meta-)memory effects of repeated checking.

Check duration

Results depicted in Figure 2-A suggest that all conditions had shorter check durations after repeated checking. To assess the effect of repeated checking on check duration, a 2 x 3 mixed ANOVA, with Time (pre-test, post-test) as within-groups variable and Condition (R-, IR, R+) as between-groups variable was carried out. It was predicted that repeated relevant checking would lead to a decline in check duration. This was reflected in main effects of Time, F (1,101) = 281.24, p < .001, η_p^2 = .74, and Condition, F (2,101) = 3.91, p < .05, η_p^2 = .07, which were qualified by a marginally significant Time x Condition interaction, F (2,101) = 3.0, p = .054, η_p^2 = .06. Although check duration decreased as a result of repeated checking for all three conditions, all Fs (1,101) > 64, ps < .001, η_p^2s > .39, the decline in check duration was larger for the relevant checking without defamiliarization condition (R-) than for the irrelevant checking condition (IR), t (68) = 2.35, p < .05, d = .56. However, the reductions in check duration did not differ between relevant checking without (R-) and relevant checking with defamiliarization (R+), t (69) = 1.77, p = .08, while a post hoc comparison revealed no significant difference between R+ and IR, t (65) = .65, p =.50. Our second hypothesis regarding check duration data was supported: repeated relevant checking led to faster performance on the checking task. However, our third hypothesis (defamiliarization leads to de-automatization) was not confirmed, because the relevant checking conditions showed no differences in checking duration.

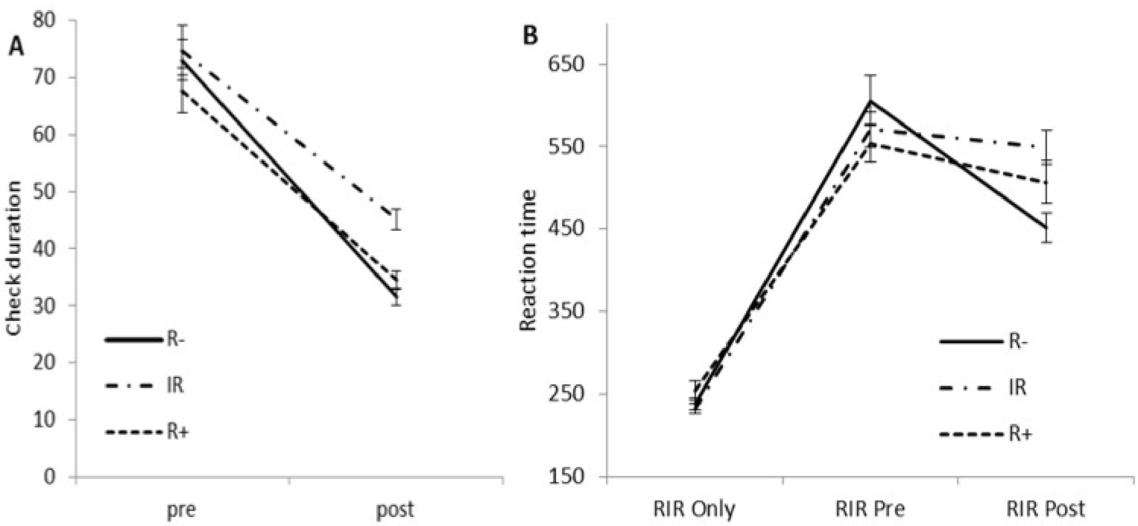

Figure 2: (A) Mean check duration (s) before and after repeated checking, and (B) mean reaction times (ms) on the Rapid Interval Repetition (RIR) task for the relevant checking without defamiliarization condition (R-), the irrelevant checking condition (IR), and the relevant checking with defamiliarization condition (R+) in Experiment I.

Reaction times: Rapid Interval Repetition (RIR) task

Figure 2-B shows a decrease in RTs for relevant checking without defamiliarization (R-) from the pre-test to the post-test, but not for irrelevant checking (IR) or relevant checking with defamiliarization (R+). The 3 (Time) x 3 (Condition) RM ANOVA on the RIR Pre to RIR Post data showed a main effect of Time, F (2,100) = 469.16, p < .001, η_p^2 = .90,

which was qualified by a Time x Condition interaction, F (4,202) = 6.82, p < .001, η_p^2 = .12. Simple main effects analyses revealed that the RIR Only to RIR Pre increases were significant for all three conditions (all M_{diff}s > 301, all Fs (2,100) > 133.46, all ps < .001, all η_p^2s >.73). The RIR Pre to RIR Post decreases were significant for R-, M_{diff} = 154, p <.001, and R+, M_{diff} = 47, p <.05, while there was no significant reduction for IR, M_{diff} = 22, p =.32. Furthermore, the RIR Pre to RIR Post decline for R- differed significantly from IR, t (68) = 4.10, p < .001, d = .99, and from R+, t (69) = 3.34, p < .01, d = .80. A post hoc comparison revealed no significant difference in RT reductions between R+ and IR, t (65) < 1, p = .37. Our second hypothesis (checking performance and RTs are faster after repeated relevant checking), was also supported with regard to the RT data. Our third hypothesis (defamiliarization leads to de-automatization) was also supported, because relevant checking with defamiliarization (R+) led to a smaller decline in RTs than relevant checking without defamiliarization (R-).

Discussion

As predicted, repeated relevant checking led to reductions in memory confidence, vividness and detail, while memory accuracy remained unchanged. Furthermore, repeated relevant checking, compared to irrelevant checking, led to improved performance on both the checking task (measured as shorter check durations) and the secondary RT task (measured as faster RTs). The reductions in check duration and RTs indicate that repeated relevant checking leads to automatization of checking behavior.

Results on the effects of the defamiliarization procedure were mixed. Although it did lead to increased RTs on the secondary RT task, compared to relevant checking without defamiliarization, it did not increase check duration. Apparently, defamiliarization did not lead to de-automatization of the checking procedure itself, but did reduce cognitive capacity for the secondary RT task. In contrast to the fourth hypothesis, defamiliarization did not attenuate the negative effects of repeated checking on meta-memory. Although we increased the degree of defamiliarization in the current study, the reductions in memory confidence, vividness, and detail after repeated checking were similar to the Dek et al. (2014) study. However, this may not be surprising, because the check duration results showed that checking behavior was still automated after defamiliarization; therefore, one might not expect attenuated subjective meta-memory ratings.

So, although the increase in the degree of defamiliarization did not affect check duration or diminish the detrimental effects of checking on meta-memory, cognitive capacity on the secondary RT task was reduced after defamiliarization. In contrast, the defamiliarization procedure used by Dek et al. (2014) did not lead to longer check durations or slower RTs. The findings of Experiment I suggest that an even larger degree of defamiliarization may be required to induce de-automatization of checking behavior and reduce memory uncertainty. This was the aim of Experiment II. We decided to replicate Experiment I using the same task and procedure, but with enhancements of the color modification procedure in the relevant checking with defamiliarization condition. The degree of defamiliarization was increased further by enlarging the amount of color alterations.

Experiment II

Method

Participants

Participants were 116 students from Utrecht University and Utrecht University of Applied Sciences. Prior to the statistical analyses, two participants were removed from the dataset because of incomplete data, and three participants with a self-reported ADD/ADHD diagnosis were removed. As a result, 111 participants (81 females, 30 males) remained. They were, on average, 21.1 (SD = 2.9) years old, and were given a small remuneration or course credit for their participation.

Procedure and computer task

The method of Experiment II was similar to Experiment I, except for the virtual stimuli in the checking task.

Checking task

During the training phase, the pre-test and the 15 checking trials, the six large circles with a star in it were all colored green + red (see Figure 3-A) in all three conditions (except for the 15 checking trials in the irrelevant condition, in which small grey circles were presented, cf. Experiment 1). In order to induce defamiliarization, we modified the color of all stimuli in the relevant checking with defamiliarization condition at the post-test. The color of the circles + stars was altered from green circles + red stars into black circles + white stars (2 x), purple circles + yellow stars (2 x), and blue circles + orange stars (2x; see Figure 3-B). The color of the six turning knobs was altered from grey to red, white, blue, orange, green and purple. The background color was altered from dark grey into bright blue. To prevent potential confounding effects, we did not counterbalance the color of the stimuli across other phases and conditions.

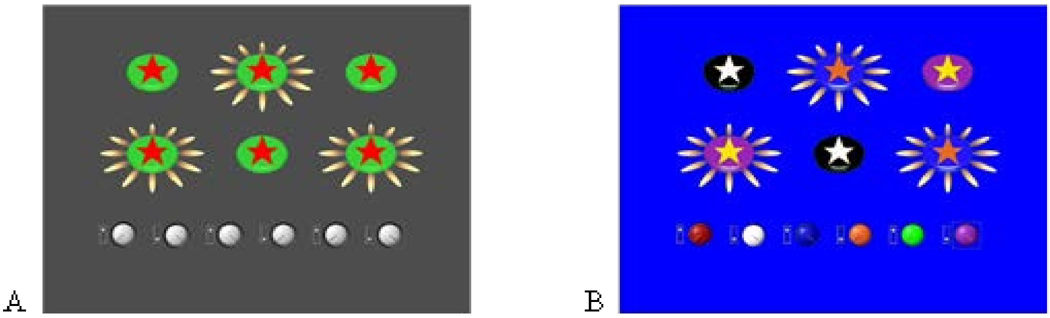

Figure 3: Illustration of (A) stimuli without defamiliarization at the pre-test and the 15 relevant checking trials of the checking task, and (B) stimuli with strong defamiliarization at the post-test of the checking task for the relevant checking with defamiliarization condition (R+) in Experiment II

Assessments

Assessments were identical to those of Experiment I.

Data modification

Checking task

Data from one participant (R- condition) were excluded from analyses, because the mean check duration exceeded *M* + 3 *SD* from the group mean.

Statistical analyses

Statistical analyses were similar to Experiment I. The Pearson correlations of memory confidence, vividness, and detail at the pre-test suggested that MANOVA was appropriate (memory confidence and vividness, r = .58; memory confidence and detail, r = .56; vividness and detail, r = .67, all *p*s <.001). Two separate ANOVAs examined the effect of repeated checking on check duration and RT, because Check duration at the pre-test did not correlate with RIR Pre (r = .04, p = .70).

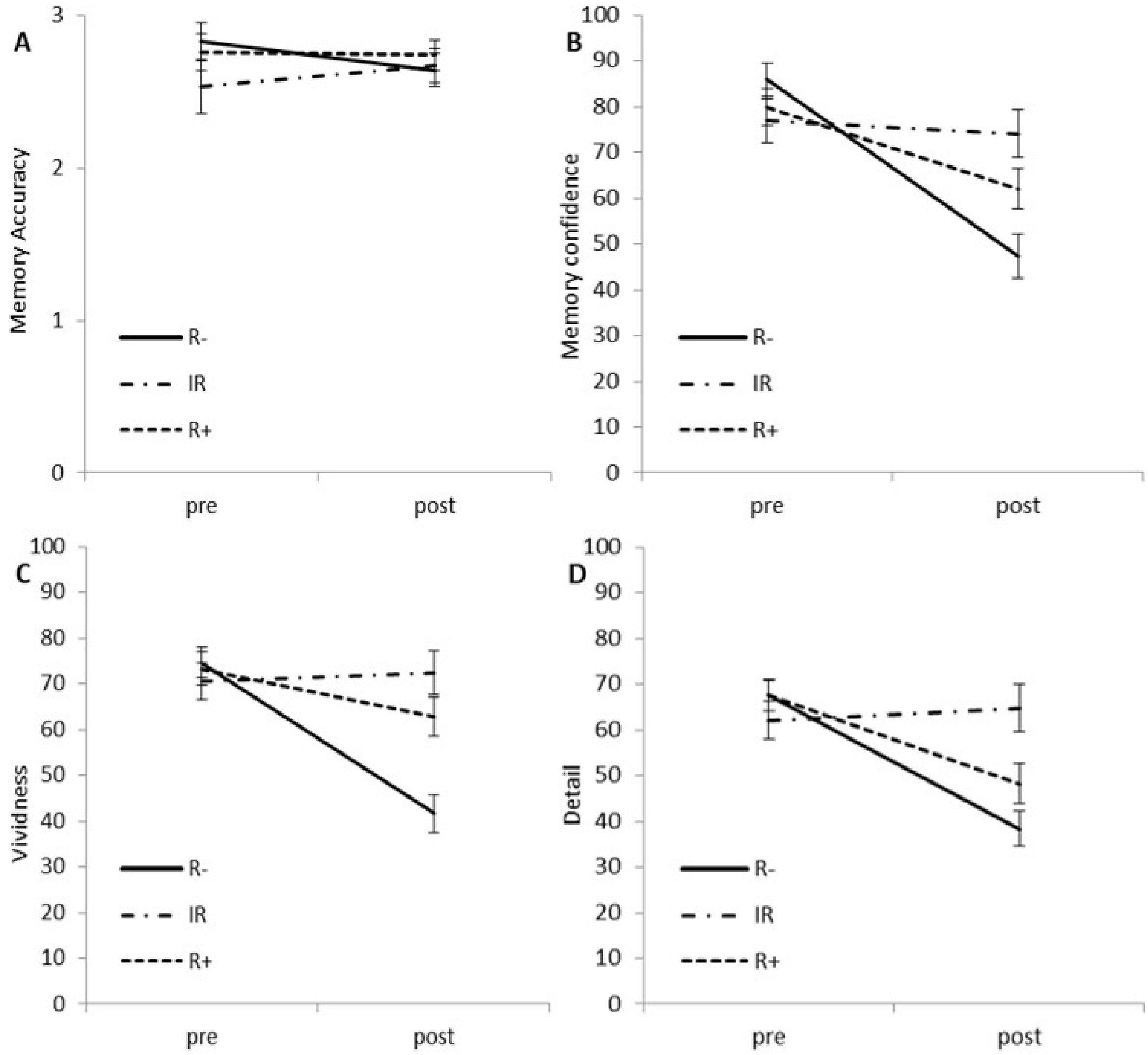

Figure 4: Mean ratings before and after repeated checking for (A) memory accuracy, (B) memory confidence, (C) vividness, and (D) detail, for the relevant checking without defamiliarization condition (R-), the irrelevant checking condition (IR), and the relevant checking with defamiliarization condition (R+) in Experiment II.

Results

Experimental conditions

One hundred-and-ten participants were included in the analyses (n = 36 in R-, n = 36 in IR, and n = 38 in R+). Conditions were similar regarding age, F (2,107) = 1.86, p = .16, and gender, χ^2 (2, N = 110) = 3.51, p = .17.

Memory accuracy

Figure 4-A shows that results were comparable to Experiment I: repeated relevant checking did not affect memory accuracy. This was reflected by results of the 2 (Time: pre-test, post-test) x 3 (Condition: R-, IR, R+) RM ANOVA, which showed no significant main effects or interaction effect, Fs < .94.

Memory confidence, vividness and detail

Figure 4 B-D depicts results on the effects of repeated checking on memory confidence, vividness, and detail. The RM MANOVA with memory confidence, vividness and detail as dependent variables showed the predicted Time x Condition interaction, F (6,212) = 5.45, p <.001, η_p^2 = .13. To test whether repeated relevant checking reduced *confidence in memory*, a 2 x 3 RM ANOVA, with Time (pre-test, post-test) as within-groups factor and Condition (R-, IR, R+) as between-groups factor, was performed. It was predicted that repeated relevant checking would lead to memory uncertainty, and that defamiliarization would reduce the negative effects of repeated checking on memory confidence. There was a main effect of Time, F (1,107) = 33.07, p <. 001, η_p^2 = .24, which was qualified by a Time x Condition interaction, F (2,107) = 9.06, p < .001, η_p^2 = .15. Simple main effects analyses showed that after confidence in memory declined after relevant checking without defamiliarization (R-), F (1,107) = 41.60, p <.001, η_p^2 = .28, and after relevant checking with defamiliarization (R+), F (1,107) = 9.27, p <.01, η_p^2 = .08, but not after irrelevant checking (IR), F (1,107) < 1, p = .65. Crucial to the aim of this experiment, the decline in memory confidence was significantly smaller for R+ than for R-, t (72) = 2.65, p < .05, d = .61, and did not differ from IR, t (72) = 1.84, p = .07, while the decline in memory confidence was significantly larger for R- compared to IR, t (70) = 3.93, p < .001, d = .93.

The mixed ANOVA on *vividness of memory* showed similar results. Main effects of Time, F (1,107) = 23.40, p <. 001, η_p^2 = .18, and Condition, F (2,107) = 4.71, p <. 05, η_p^2 = .08, were qualified by a Time x Condition interaction, F (2,107) = 12.56, p < .001, η_p^2 = .19. The reductions in vividness were significant for R-, F (1,107) = 43.59, p <.001, η_p^2 = .29, and R+, F (1,107) = 4.60, p <.05, η_p^2 = .04, and there was no reduction in vividness for IR, F (1,107) < 1, p = .70. Furthermore, the decline in vividness was significantly smaller for R+ than for R-, t (72) = 3.42, p < .01, d = .79, and did not differ from IR, t (72) = 1.83, p = .07, and the decline in vividness was significantly larger for R- than for IR, t (70) = 4.57, p < .001, d = .96.

Results of the RM ANOVA on *memory detail* indicated a main effect of Time, F (1,107) = 30.14, p <. 001, η_p^2 = .22, which was qualified by a Time x Condition interaction, F (2,107) = 11.22, p < .001, η_p^2 = .17. The reductions in detail were significant for R-, F (1,107) = 35.79, p <.001, η_p^2 = .25, and R+, F (1,107) = 16.80, p <.001, η_p^2 = .14, but there was no reduction in detail for IR, F (1,107) < 1, p = .59. Furthermore, the decline in detail was significantly larger for R- than for IR, t (70) = 4.43, p < .001, d = 1.04. R+ did not differ from R-, t (72) = 1.47, p = .15, but did differ from IR, t (72) = 3.30, p = .001, d = .77.

Consistent with Experiment I, and in line with our first hypothesis, repeated relevant checking while performing a secondary RT task led to reductions in memory confidence, vividness, and detail, but did not affect memory accuracy. Furthermore, our fourth hypothesis (defamiliarization reduces the negative meta-memory effects of repeated checking) was supported for memory confidence and vividness, but not for detail of memory.

Check duration

Data depicted in Figure 5-A suggest that all conditions had shorter check durations after repeated checking. This was reflected by results from the 2 (Time) x 3 (Condition) mixed ANOVA, which indicated a main effect of Time, F (1,107) = 310.53, p < .001, η_p^2 = .74, that was qualified by a Time x Condition interaction, F (2,107) = 4.80, p = .01, η_p^2 = .08. Simple main effects analyses showed that check duration decreased as a result of repeated checking for relevant checking without defamiliarization (R-), irrelevant checking (IR), and relevant checking with defamiliarization (R+), all Fs (1,107) > 59, ps < .001, η_p^2s > .35. The decline in check duration was larger for R- than for IR, t (70) = 2.92, p < .01, d = .69, and the reductions in check duration did not differ between R- and R+, t (72) = 1.08, p = .29. A post hoc comparison revealed no significant difference in check duration reductions between R+ and IR, t (72) = 2.07, p =.04. In accordance with Experiment I, and in line with our second hypothesis regarding check duration, repeated checking led to faster performance on the checking task. However, because there was no difference in check duration reductions between the relevant checking conditions, our third hypothesis (defamiliarization leads to de-automatization) was, again, not confirmed.

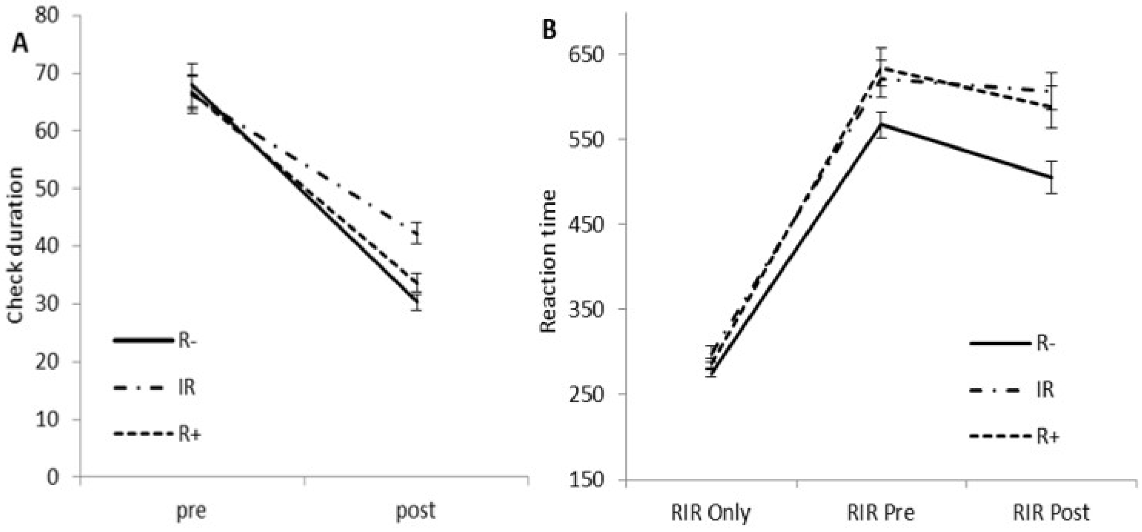

Figure 5: (A) Mean check duration (s) before and after repeated checking, and (B) mean reaction times (ms) on the Rapid Interval Repetition (RIR) task for the relevant checking without defamiliarization condition (R-), the irrelevant checking condition (IR), and the relevant checking with defamiliarization condition (R+) in Experiment II.

Reaction times: Rapid Interval Repetition (RIR) task

Figure 5-B suggests small declines in RTs from the pre-test to the post-test for relevant checking without defamiliarization (R-) and relevant checking with defamiliarization (R+), but not for irrelevant checking (IR). The 3 x 3 RM ANOVA showed main effects of Time, F (2,106) = 489.23, p < .001, $\eta_p{}^2$ = .90, and Condition, F (2,107) = 5.71, p < .01, $\eta_p{}^2$ = .10, which were qualified by a Time x Condition interaction, F (4,214) = 2.49, p <.05, $\eta_p{}^2$ = .04. Simple main effects analyses revealed that the RIR Only to RIR Pre increases were significant for all three conditions (all M_{diff}s > 293 ms, all Fs (2,106) > 127.93, all ps < .001, all $\eta_p{}^2$s >.71). The RIR Pre to RIR Post decreases were significant for R-, M_{diff} = 61, p <.01, and R+, M_{diff} = 47, p <.05, but there was no significant reduction in RT for IR, M_{diff} = 14, p =.48. The RIR Pre to RIR Post decline for R- differed marginally significantly from IR, t (70) = 1.92, p =.059, d = .45, and there was no significant difference in RT reduction between R- and R+, t (62.13) = .55, p =.58. A post hoc comparison revealed no significant difference in RT reductions between R+ and IR, t (72) = 1.10, p = .27.

Our second hypothesis (repeated relevant checking leads to faster performance on the checking task and secondary RT task) was largely supported with the RT data. The relevant checking with defamiliarization condition showed a decline in RTs, which did not differ from to the other conditions; therefore, our third hypothesis (defamiliarization leads to de-automatization) was rejected.

Discussion

In line with Experiment I, repeated relevant checking, compared to irrelevant checking, led to reductions in memory confidence, vividness, and detail, and did not affect memory accuracy. Furthermore, repeated relevant checking led to faster checking behavior and faster performance on the secondary RT task (i.e., automatization). However, the latter effect was marginally significant (p =.059), and therefore should be interpreted with caution. The combination of shorter check durations and faster responses on the secondary task seems to provide evidence for automatization as a result of repeated relevant checking.

Contrary to our third hypothesis, but in line with Experiment I, results on the effects of defamiliarization indicate that relevant checking with defamiliarization did not lead to longer check duration relative to relevant checking without defamiliarization. Furthermore, contrary to our third hypothesis and Experiment I, the decline in RTs was not smaller after defamiliarization. In short, defamiliarization did not lead to de-automatization.

Crucial to the aim of Experiment II is that defamiliarization attenuated the negative effects of repeated checking on memory confidence and vividness. Apparently, reducing familiarity by enlarging the amount of color modifications of the stimuli, knobs, and background increased confidence in memory and vividness of the recollection of the last check. Reductions in detail were not attenuated by defamiliarization, although the pattern was similar. In summary, it appears that while participants in the defamiliarization condition did not show signs of de-automatization of checking procedures or reduced cognitive capacity on the RT task, a large amount of defamiliarization can actually reduce the detrimental effects of perseverative checking on memory confidence and vividness.

General Discussion

The aim of the present research was to replicate and extend findings of Dek et al. (2014). First, we investigated whether repeated checking (while performing a secondary RT task) would lead to reductions in memory confidence, vividness, and detail, without affecting memory accuracy. Second, we tested whether perseverative checking leads to automatization using two measures: (shorter) duration of the checking procedure and (faster) responses on a secondary RT task. Third, we tested whether defamiliarization would lead to de-automatization of the checking procedure, which would be demonstrated by smaller declines in check duration and smaller reductions in RT. Finally, we investigated whether defamiliarization could attenuate the negative effects of repeated checking on memory confidence, vividness and detail. Building on the Dek et al. study (2014), we increased the degree of defamiliarization in Experiment I and even more in Experiment II.

Main findings

The main findings are the following. First, both experiments show that perseverative checking leads to reductions in memory confidence, vividness, and detail, but does not affect memory accuracy. This replicates earlier research (Boschen & Vuksanic, 2007; Coles et al., 2006; Dek et al., 2010; van den Hout & Kindt, 2003a, 2003b; 2004; Radomsky et al., 2006). Second, repeated relevant checking led to a larger decline in check duration than irrelevant checking, and led to faster responses on the secondary RT task. This is in line with our second hypothesis. However, it should be noted that in Experiment II, the decline in RT for the relevant checking condition differed marginally (p =.059) from the slope of the irrelevant checking condition.

Third, the effects of defamiliarization were mixed. With respect to check duration, the results did not support our third hypothesis: both moderate (Experiment 1) and strong (Experiment 2) defamiliarization did not increase the duration of checking behavior. However, with respect to the RT task, results of defamiliarization were inconsistent. In line with the hypothesis, Experiment I showed reduced cognitive capacity after moderate defamiliarization, as expressed by slower RTs for the defamiliarization condition. Unexpectedly, this effect was not found in Experiment II: there were no differences in RT reductions between the relevant checking conditions. Thus, it appears that the effect is fragile at best.

Fourth, reducing familiarity did not attenuate the negative effects of perseverative checking on meta-memory in Experiment I (moderate defamiliarization), but did attenuate the decrease in memory confidence and vividness in Experiment II (strong defamiliarization). Experiment II confirms findings by Boschen and colleagues (2011) that perceptual modification can attenuate the meta-memory effects of checking. These studies suggest that a strong degree of perceptual defamiliarization is necessary to attenuate these effects. Arguably, the effects on meta-memory (and especially memory confidence) are the most important ones for the understanding of OCD. The observation that the effects of checking on meta-memory can be significantly reduced by defamiliarization is in line with the suggestion that automatization is the driving force behind the well documented effects of checking on memory confidence. However, defamiliarization did not have consistent effects on de-automatization.

Limitations and future directions

Some considerations and limitations should be taken into account. First, the irrelevant checking condition also showed significant reductions in check duration, albeit significantly smaller than both relevant checking conditions. The most likely explanation is the strong resemblance of motor behaviors: both relevant conditions and the irrelevant condition demanded the execution of checking behavior by moving the computer mouse. For replication purposes, we used the same procedure as Dek and colleagues (2014), but future research may modify the checking procedure for the irrelevant condition, for example, by using the keyboard instead of the mouse.

Second, although defamiliarization reduced the drop in memory confidence and vividness in Experiment II, there was no significant effect on memory detail, although the pattern was similar. These findings were inconsistent with Experiment I and the Dek et al. study (2014) which found no effects of defamiliarization. Therefore, one may wonder whether the results on confidence and vividness in Experiment II represent chance findings/Type I errors. The confidence intervals for memory confidence and vividness for the relevant checking without defamiliarization condition (R-) and the relevant checking with defamiliarization condition (R+) provide more information on this matter. With respect to the decrease in memory confidence, the 95% confidence interval was [26.74, 50.48] for R-, and [6.19, 29.29] for R+. For the reduction in vividness, it was [23.07, 42.87] for R-, and [0.79, 20.06] for R+. All of these intervals have broad ranges, which indicate that there is still uncertainty regarding the actual difference between the relevant conditions, and replication studies are required to make firm conclusions. However, the broad confidence intervals overlap only slightly for memory confidence, and not at all for vividness, which indicates a robust difference between the relevant conditions as a result of defamiliarization.

Third, both experiments of the current investigation indicate that, contrary to our hypothesis, defamiliarization does not affect duration of the checking procedure. Experiment II showed that defamiliarization reduced the drops in memory confidence and vividness of the recollection, but the checking behavior itself was still automated. How can this be explained? A possible explanation might be our operationalization of automatization. Since decades there has been a debate about the defining features of automaticity in social science (for an overview, see Moors & de Houwer, 2006). Although our results provide indications of automatization as a result of repeated checking, it is possible that we chose sub-optimal parameters to measure automatization (i.e., efficiency), and that other features of automaticity, for example, unintentional and uncontrollable (Bargh, 1994), play a more profound role. A further discussion of this subject is outside the scope of this paper.

The fact that we tested a healthy sample and did not incorporate anxiety into the design of our study may be considered limitations as well. However, we deliberately chose the use of threat-irrelevant stimuli, because we wanted to study how automaticity develops in perseverative behavior in healthy participants. In order to investigate efficiency differences in perseverative behavior in OCD, a next step would be to study threat-irrelevant checking in a clinical sample. Perhaps automaticity of routines is not a problem for healthy participants, but is problematic for patients with OCD, who feel a strong need to exert control over their daily-life routines, which “would otherwise operate in automatic and well-practiced ways” (Salkovskis, 1998, p. 40). To examine the clinical validity of the present study, we are currently conducting an experiment in patients with OCD. A direction for future research would be to administer the present task with threat-relevant stimuli to OCD patients. Because of the heterogeneity of symptom presentations in OCD, it might be more convenient to use an overarching factor to induce emotional load rather than idiosyncratic stimuli. Boschen and Vuksanovic (2007) induced an emotional load by adding a responsibility condition to the checking task (i.e., they made participants believe that another person would receive a mild shock if they would not turn off the stove correctly). They found that in case of high perceived responsibility, reductions in memory confidence were larger for OCD patients compared to controls. The question remains whether efficiency is reduced by using threat-relevant stimuli in patients with OCD. A recent review of literature on automatic processing in anxiety disorders (Teachman et al., 2012) indicated elevated automatic processing of threat-relevant information in OCD (i.e., moderate support for elevated unconscious processing, little support for uncontrollable processing but strong support for difficulties in thought suppression, and minimal support for unintentional processing). Automatic processing of the emotional information inherent to threat-relevant stimuli in the checking task might reduce the efficiency with which OCD patients execute the checking procedure and secondary RT task.

Theoretical and clinical implications

A first implication of this study is that it confirms the paradoxical perseveration model of OCD: repeated checking leads to reductions in memory confidence, vividness, and detail, while memory accuracy remains unaffected. Second, this study helps to understand how the perseveration effects are caused. When obsessive-compulsive behavior is induced, repetition and increased familiarity with the stimuli lead to automatization of the act of checking.

Checking becomes more efficient: the extent to which the automated checking procedure demands attentional resources is diminished. The recollection of a check becomes less vivid and detailed, which leads to reduced memory confidence. Although replication of the results is required, defamiliarization seems to reduce automaticity: demands on attentional resources are increased. Furthermore, a strong degree of defamiliarization reduces drops in vividness and memory confidence. A third implication of this study is that it provides a powerful theoretical and empirical rationale for ritual prevention in the exposure treatment of OCD. Although our main objective was to use defamiliarization as a measure to test the automaticity hypothesis, the defamiliarization results have potential clinical implications. Besides adding to the understanding of the perseveration model of OCD, defamiliarization can be used as an experiential illustration of the paradoxical perseveration phenomenon as part of psycho-education during treatment, and can be incorporated into behavioral experiments (which was also suggested by Shafran, Radomsky, Coughtrey, & Rachman, 2013). Radomsky (2014) demonstrated the additional value of using experimental designs in behavioral experiments as a treatment method. For instance, colorful stickers may be put on stimuli like door handles and light knobs in order to defamiliarize them. This way, patients can experience the positive effects on meta-memory, which might help to motivate them to abstain from ritualizing. Although positive effects of 'defamiliarization' have been reported in clinical practice, the use of defamiliarization as a new intervention technique to reduce obsessive-compulsive symptoms on a long term basis seems unwarranted. For example, when patients go on holiday, which implies a drastic change of 'familiar' stimuli (e.g., another stove, different door locks) and context (e.g., different apartment, different kitchen), they frequently report large reductions in OCD symptoms. However, over the course of the holiday symptoms usually increase. The present study suggests that the short-term duration of these effects might be explained by increased familiarity and repetition with the initially 'defamiliarized' stimuli.

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References

Ashbaugh, A. R., & Radomsky, A. S. (2007). Attentional focus during repeated checking influences memory but not metamemory. *Cognitive Therapy and Research, 31*, 291-306. http://dx.doi.org/10.1007/s10608-006-9087-9

Bargh, J. A. (1994). The four horsemen of automaticity: awareness, intention, efficiency, and control in social cognition. In R. S. Wyer & T. K. Srull (Eds.), *Handbook of social cognition* (Vol. 1, pp. 1-40). Hillsdale, NJ: Erlbaum.

Boschen, M. J., & Vuksanovic, D. (2007). Deteriorating memory confidence, responsibility perceptions and repeated checking: Comparisons in OCD and control samples. *Behaviour Research and Therapy, 45*, 2098-2109. http://dx.doi.org/10.1016/j.brat.2007.03.009

Boschen, M. J., Wilson, K. L., & Farrell, L. J. (2011). Attenuating memory distrust in a repeated checking task. *Behavioural Research and Therapy, 49,* 466-471. http://dx.doi.org/10.1016/j.brat.2011.05.001

Brebner, J. M. T., & Welford, A. T. (1980). In. A.T. Welford, *Reaction Times* (pp. 1-23).New York: Academic Press.

Coles, M.E., Radomsky, A.S., & Horng, B. (2006). Exploring the boundaries of memory distrust from repeated checking: Increasing external validity and examining thresholds. *Behaviour Research and Therapy, 44*, 995-1006. http://dx.doi.org/10.1016/j.brat.2005.08.001

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology, 36*, 28-71. http://dx.doi.org/10.1006/cogp.1998.0681

Dek, E. C. P., van den Hout, M. A., Engelhard, I. M. & Giele, C. L. (2010). Repeated checking causes distrust in memory but not in attention and perception. *Behaviour Research and Therapy, 48*, 580-587. http://dx.doi.org/10.1016/j.brat.2010.03.009

Dek, E. C. P., van den Hout, M. A., Giele, C. L., & Engelhard, I. M. (2014). Automatization and familiarity in repeated checking. *Journal of Obsessive Compulsive and Related Disorders, 3,* 303-310. http://dx.doi.org/10.1016/j.jocrd.2014.07.001

van den Hout, M. A., & Kindt, M. (2003a). Repeated checking causes memory distrust. *Behaviour Research and Therapy, 41*, 301-316. http://dx.doi.org/10.1016/S0005-7967(02)00012-8

van den Hout, M.A., & Kindt, M. (2003b). Phenomenological validity of an OCD-memory model and the remember/know distinction. *Behaviour Research and Therapy, 41*,369-378. http://dx.doi.org/10.1016/S0005-7967(02)00097-9

van den Hout, M. A., & Kindt, M. (2004). Obsessive-compulsive disorder and the paradoxical effects of perseverative behaviour on experienced uncertainty. *Journal of Behavior Therapy and Experimental Psychiatry, 35*, 165-181. http://dx.doi.org/10.1016/j.jbtep.2004.04.007

Johnston, W. A. & Hawley, K. J. (1994). Perceptual inhibition of expected inputs: the key that opens closed minds. *Psychological Bulletin & Review, 1*, 56-72. http://dx.doi.org/10.3758/BF03200761

Karni, A., & Sagi, D. (1991). Where practice makes perfect in texture discrimination: Evidence for primary visual cortex plasticity. *Proceedings of the National Academy of Sciences, 88*, 4966-4970. http://dx.doi.org/10.1073/pnas.88.11.4966

Lassaline, M. E., & Logan, G. D. (1993). Memory-based automaticity in the discrimination of visual numerosity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 561-581. http://dx.doi.org/10.1037/0278-7393.19.3.561

Lockhart, R. S., & Craik, F. I. M. (1990). Levels of processing: A retrospective commentary on a framework for memory research. *Canadian Journal of Psychology, 44*, 87-112. http://dx.doi.org/10.1037/h0084237

McNally, R. J. (1995). Automaticity and the anxiety disorders. *Behaviour Research and Therapy, 33*, 747-754. http://dx.doi.org/10.1016/0005-7967(95)00015-P

Moors, A. & Houwer, J. de (2006). Automaticity: A theoretical and conceptual analysis. *Psychological Bulletin, 132*, 297-326. http://dx.doi.org/10.1037/0033-2909.132.2.297

Radomsky, A. S., Gilchrist, P. T., & Dussault, D. (2006). Repeated checking does cause memory distrust. *Behaviour Research and Therapy, 44*, 305-316. doi:10.1016/j.brat.2005.02.0

Radomsky, A. S., & Alcolado, G. M. (2010). Don't even think about checking: mental checking causes memory distrust. *Journal of Behavior Therapy and Experimental Psychiatry, 41*, 345-351. http://dx.doi.org/10.1016/j.jbtep.2010.03.005

Radomsky, A. S. (2014, September). *Innovations in understanding and treating OCD: bridging the gap between the lab and the clinic.* Keynote presented at the annual congress of European Association for Behavioural and Cognitive Therapies (EABCT), The Hague, The Netherlands.

Roediger, H. L. (1990). Implicit memory. Retention without remembering. *American Psychologist, 45*, 1043-1056. http://dx.doi.org/10.1037/0003-066X.45.9.1043

Ruscio, A. M., Stein, D. J., Chiu, W. T., & Kessler, R. C. (2010). The epidemiology of obsessive-compulsive disorder in the National Comorbidity Survey Replication. *Molecular Psychiatry, 15,* 53-63. http://dx.doi.org/10.1038/mp.2008.94

Salkovskis, P. M. (1998). Psychological approaches to the understanding of obsessional problems. In R. P. Swinson, M. M. Antony, S. Rachman, & M. A. Richter (Eds.), *Obsessive-compulsive disorder* (pp. 33-50). New York: Guilford Press.

Shafran, R., Radomsky, A. S., Coughtrey, A. E., & Rachman, S. (2013). Advances in the cognitive behavioural treatment of obsessive compulsive disorder. *Cognitive Behaviour Therapy, 42*, 265-274. http://dx.doi.org/10.1080/16506073.2013.773061

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review, 84*, 127-190. http://dx.doi.org/10.1037//0033-295X.84.2.127

Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics* (5th ed.). Boston: Allyn & Bacon.

Tallis, F. (1993). Doubt reduction using distinctive stimuli as a treatment for compulsive checking: An exploratory investigation. *Clinical Psychology & Psychotherapy, 1*, 45-52. http://dx.doi.org/10.1002/cpp.5640010107

Tallis, F. (1995). *Obsessive Compulsive Disorder. A cognitive and neuropsychological perspective.* Chichester: Wiley.

Teachman, B. A., Joormann, J., Steinman, S. A., & Gotlib, I. H. (2012). Automaticity in anxiety disorders and major depressive disorder. *Clinical Psychology Review, 32*,575-603. http://dx.doi.org/10.1016/j.cpr.2012.06.004

Vandierendonck, A., Voogt, G. de, & Goten, K. van der (1998). Interfering with the central executive by means of a random interval repetition task. *Journal of Experimental Psychology, 51A*, 197-218. http://dx.doi.org/10.1080/713755748