Does repeated checking really cause memory distrust?

Improving the computer task

Repeatedly checking the same class of items results in sharp decreases in the meta-memory (i.e. confidence, detail and vividness) (e.g. van den Hout & Kindt, 2003a, 2004; Radomsky & Alcolado, 2010). Multiple researches have studied this phenomenon and often the computer task created by van den Hout and Kindt (2003a) was used (e.g. Boschen & Vukcanovic, 2007; Dek, van den Hout, Engelhard, Giele & Cath, 2015; Dek, van den Hout, Giele & Engelhard 2010). However, it has recently and accidentally been noted in the clinical psychology lab of Utrecht University that this task contained an error. Participants spend noticeably less time on the control condition than the experimental condition, which indicates that the control condition is simpler. Therefore, a new computer task was developed in which both conditions should be equally difficult. The process of developing the task was supported by two pilot studies. The aim of the current study was to show that the new task has equal conditions and to replicate findings of previous studies. Eighty-four participants performed the new checking task in which they first checked either a gas stove or light bulbs at pre-test and answered questions about the meta-memory variables. Following, 20 checks were completed of one of these objects, and finally they checked the same object as they checked at pre-test and answered the questions once more. Results showed that the mean checking time was significantly lower in the gas stove checking trial than in the light bulb checking trial. Additionally, as we hypothesized, repeated checking resulted in decreased meta-memory scores. In conclusion, the adaptions to the computer task by van den Hout and Kindt (2003a) were not sufficient in providing a new computer task with equal conditions. Nevertheless, information about how to adjust this task was provided. Moreover, the study replicated findings of former research about repeated checking affecting the meta-memory, successfully.

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Introduction

Obsessive-compulsive disorder (OCD) is a disorder characterized by obsessions and compulsions. The obsessions consist of recurrent intrusive thoughts, images or urges that typically cause anxiety and distress. Compulsions are the repetitive mental and behavioural acts one feels driven to perform in response to the obsessions. Compulsive checking is the single most common compulsive behaviour performed by patients with OCD (Hermans, Martens, De Cort, Pieters, & Eelen, 2003). The repeatedly checking of ones actions is considered to be a way of coping with insecurity. However, multiple studies have demonstrated that frequently checking their actions has a paradoxical effect (Ashbaugh & Radomsky, 2007; Boschen & Vuksanovic, 2007; Coles, Radomsky & Horng, 2006; Dek, van den Hout, Engelhard, Giele & Cath, 2015; Dek, van den Hout, Giele & Engelhard, 2010; van den Hout, Engelhard, de Boer, du Bois & Dek, 2008; van den Hout, Engelhard, Smeets, Dek, Turksma & Saric, 2009; van den Hout & Kindt, 2003a, 2003b, 2004; Linkovski, Kalanthroff, Henik & Anholt, 2013; Radomsky & Alcolado, 2010; Radomsky, Dugas, Alcolado & Lavoie, 2014; Radomsky, Gilchrist & Dussault, 2006). Regularly checking the same class of items results in sharp decreases in confidence, detail and vividness of memory of the checked events while the accuracy of memory remained unaffected (e.g. van den Hout & Kindt, 2003, 2004; Radomsky & Alcolado, 2010).

In these studies, participants performed a computer task by van den Hout and Kindt (2003a), which consisted of three separate components, namely a pre-test, a checking trial and a post-test. At the pre- and post-test participants check the switches on a virtual gas stove, and are asked to fill in a questionnaire on different aspects of meta-memory, such as accuracy, confidence, detail and vividness. Between the pre- and post-test half of the participant checked the switches on a gas stove twenty times, considered as ‘relevant checking’, since the stimuli were identical to those of the pre- and post-test. The other half checked the switches of light bulbs twenty times, which was ‘irrelevant checking’. In total people completed twenty checks. It was expected that meta-memory would be affected when someone checks a gas stove between the first and last check of the same gas stove. However, if people check light bulbs in between, meta-memory should not be affected.

As was hypothesized, these experiments showed that irrelevant checking does not affect the meta-memory, whereas relevant checking does have an impact on the confidence, detail and vividness of the memory (e.g. Boschen & Vuksanovic, 2007; van den Hout & Kindt, 2003a, 2003b, 2004). The effects occur both with virtual stimuli (e.g. Boschen & Vuksanovic, 2007; Dek, van den Hout, Giele & Engelhard, 2010; van den Hout & Kindt,

2003a, 2003b, 2004) and real-life stimuli (Coles et al., 2006; Radomsky et al., 2006; Radomsky & Alcolado, 2010). In addition, the effects are also observed after a relatively low number of checks (Coles et al., 2006). More importantly, these effects are not only found in healthy controls (Coles et al., 2006; van den Hout & Kindt, 2003, 2004; Radomsky et al., 2006; Radomsky, Dugas, Alcolado, &Lavoie, 2014), but also in patients with OCD (e.g. Boschen and Vuksanovic, 2007; Dek, van den Hout, Engelhard, Giele & Cath, 2014) and these effects are similar. Thus, repeated checking seems to contribute to memory distrust in all people.

However, even though the before mentioned findings have been replicated multiple times, it has recently and accidentally been noted in the clinical psychology lab of Utrecht University that this computer task contained an error. Closer examination of the data demonstrated that participants spend noticeably less time in the irrelevant condition (i.e. light bulbs as checking trial) than in the relevant condition (i.e. gas stoves as checking trial). Consequently, checking light bulbs in the irrelevant computer task appears to be simpler than checking gas stoves in the relevant task. In order to establish whether the previous findings were found due to the difference in difficulty of the task, a new computer task has been developed, in which the irrelevant task is more difficult. In addition, the new task offered the possibility to measure relevant and irrelevant checking with both a gas stove and light bulbs. This enables measurement of relevant checking by checking either light bulbs or gas stoves at the pre- and the post-test and during the twenty checks of the checking trial. In addition, participants might also be asked to check light bulbs at pre- and post-test and gas stoves during the checking trial, or gas stoves at pre- and post-test and light bulbs during the checking trial, which is considered irrelevant checking. Accordingly, we can examine whether the type of object that is checked does not influence the way in which the meta-memory is affected. Moreover, the new task provides the possibility to observe the amount of time spent on every single check.

The current study aims to replicate the findings of previous studies of the effects of repeated checking on the meta-memory, using a new computer task in which the experimental and control condition are of equal difficulty. Therefore, first of all, it is expected that the gas stove and light bulbs are just as difficult in the new computer task, which would result in equal time spend when checking either. In addition, we expect relevant checking to influence the meta-memory variables of confidence, detail and vividness, whereas irrelevant checking will not affect the meta-memory. The type of object that is checked should not affect the effect of relevant checking on the meta-memory variables. In addition, we expect the effect

size of our study to correspond with the effect sizes of the previous studies, in order to conclude whether the effects have been replicated.

Pilot 1

Introduction

First of all, a pilot-study was conducted in order to determine if the conditions of the new computer task were just as difficult. Therefore, we examined the time it took participants to check the gas stove and the light bulbs. We expected this to take just as much time in both conditions.

Participants and procedure

Ten undergraduate students participated in the pilot study. The study was conducted in a soundproof laboratory room with a table, chair and a computer. Participants were presented with an adjusted computer task. During the task, half of the participants (n=5) practiced first the gas stove once, then the light bulbs once. The other half of the participants (n=5) practiced first with the light bulbs, then the gas stove. Subsequently, participants first had to check the light bulbs ten times and then the gas stove ten times, or the other way around (see Figure 1 for an example of the virtual gas stove and light bulbs). Ultimately, there were four different conditions as presented in table 1.

Table 1. *Conditions pilot 1*

		Checking trial:	
		First light bulbs, then gas	First gas, then light bulbs
Practice trial:	First light bulbs, then gas	Condition 1	Condition 2
	First gas, then light bulbs	Condition 3	Condition 4

Participants were also asked for their informed consent and whether they had participated in a gas stove study before. None of the ten participants had ever participated in such a study. There was no reward for participation.

Figure 1. Representation of the gas stove and light bulbs in pilot study 1.

Results

As displayed in figure 2, the time spent checking the gas stove was longer than that of checking the light bulbs. Once the checking stimuli changed from light bulbs to gas stoves, the time spent on checking increased, whereas for those who checked gas stoves first, time spent checking decreased once the stimuli changed to light bulbs.

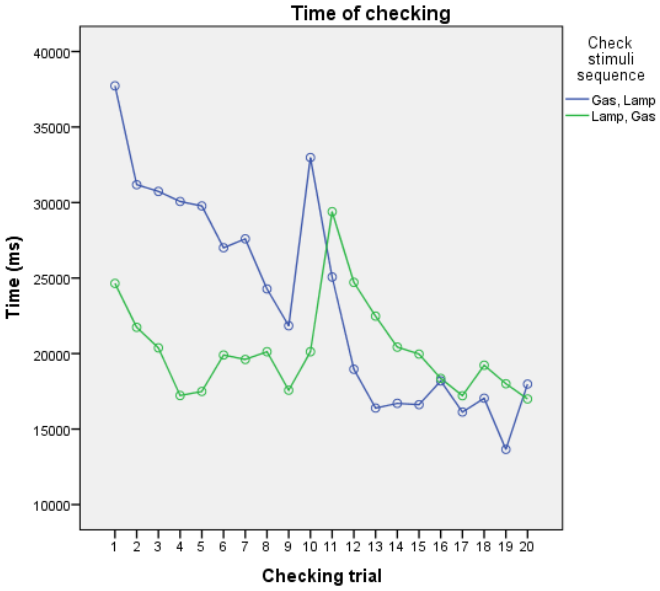


Figure 2. Results of pilot study 1.

Note. After checking trial *10* the checking stimuli changes.

Discussion

In this first pilot study, the checking of the light bulbs seems to take less time than the checking of the gas stove, which led to the conclusion that the light-bulb task was still too easy, despite the adjustments to the task. There was no statistical analysis performed, since the group of participants were considered too small for this. It was hypothesized that the gas stove task was difficult because of the movements of the mouse in order to turn the stove on and off. Participants had to make a turning movement with the mouse, whereas switching the light bulbs on and off required moving the mouse from left to right. The latter movement might be in itself faster than turning the mouse.

Pilot 2

Introduction

The findings of pilot study 1 resulted in an additional adjustment to the computer task. The goal of this pilot was to develop a computer program in which the light bulbs task was more difficult. After consideration, it was suspected that the light bulbs were too simple because of the knobs. The left-to-right motion was considered simpler and faster than the turning motion of the gas stove knobs. On that account, it was decided to change the switch of the light bulbs in an S-shape or, in other words, in two half circles like the turning knobs of the gas stove (Figure 3). Consequently, the pathways of both conditions were just as long.

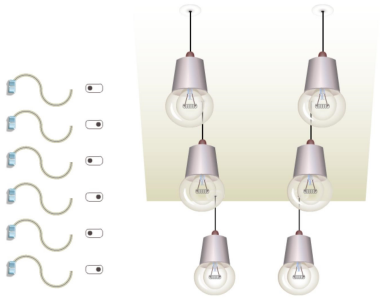


Figure 3. Representation of the light bulbs in pilot study 2.

Participants and procedure

After the computer task was adjusted, eighteen people participated in this second pilot study, which took about 15 minutes. Participants were asked for their informed consent and previous participation in a gas stove study. This study was also conducted in the soundproof laboratory rooms. Participation was rewarded with either two euros or college credit. As was the case in pilot study 1, half of the participants (n=9) practiced first the gas stove once, then the light bulbs once. The other half of the participants (n=9) practiced first with the light bulbs, then the gas stove. Subsequently, participants first had to check the light bulbs and then the gas stove ten times, or the other way around, which resulted in the same four conditions as in pilot study 1 (Table 1).

Results

A 20 x 2 repeated measures ANOVA was performed using *Time* (check 1-20; a within factor) and *Stimuli* (gas vs. light; a between factor). There was a main effect of time ($F(1, 19) = 5.63$, $p = .00$; $\eta^2 = .260$) indicating that the duration of checking decreases over time when checking either gas stoves or light bulbs. In addition, there was a significant interaction effect

of time and stimuli ($F(1, 19) = 3.945$, $p = .00$; $\eta^2 = .20$), meaning that over time checking light bulbs costs more time than checking gas stoves. These results demonstrate that currently the light bulb task took *more* time than the gas stoves as shown in figure 4.

Interestingly, not all participants disclosed prior participation in a gas stove study. However, it seemed that the duration of checking of those known not to have participated before, did not differ much in checking gas stoves versus light bulbs as shown in figure 4. No statistical analysis was performed for this subgroup, since the sample was considered too small However, the duration of checking of those known not to have participated before did not differ much.

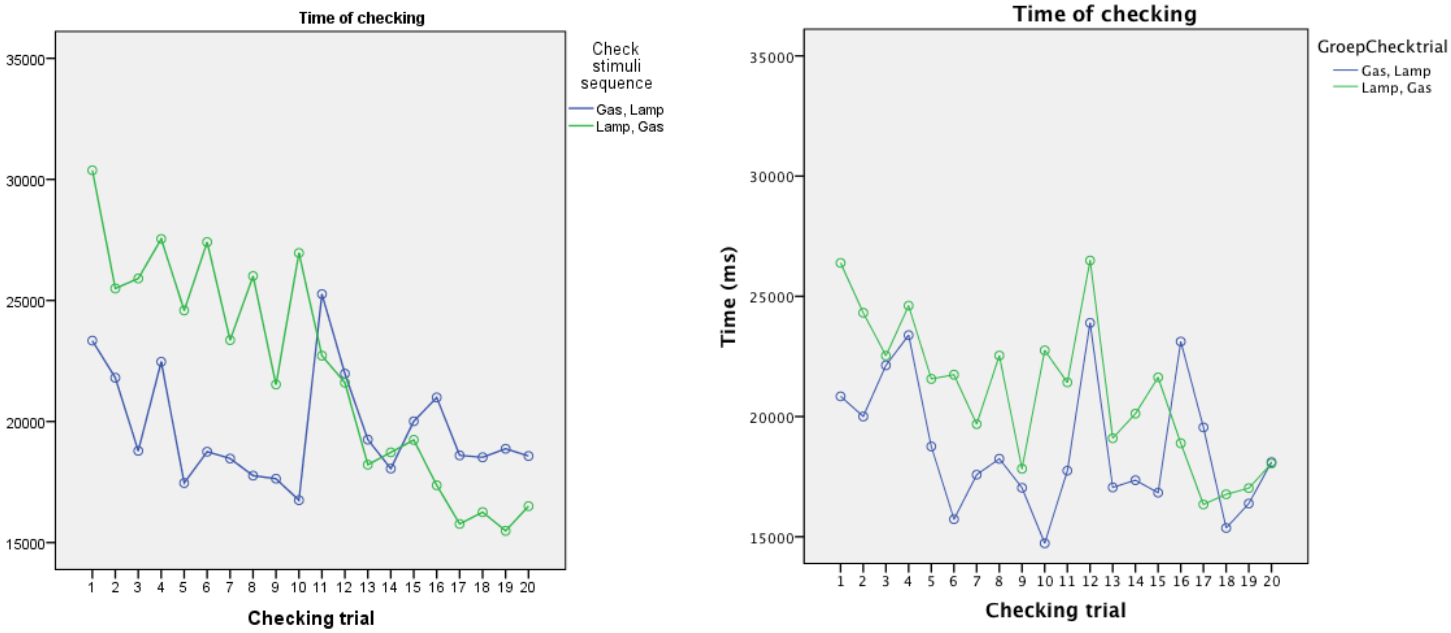


Figure 4. Results of pilot study 2 for the total sample (*left*) and for people who did not participate in a gas stove study prior (*right)*. *Note*. After checking trial *10* the checking stimuli changes.

Discussion

The second pilot study demonstrated that both tasks were still not equally difficult. However, when looking solely at participants known not to have participated in a gas stove study before, they were about as fast in both tasks. Two possible explanations might account for the difference between both tasks. Firstly, there could be a learning effect for the participants. It is possible that participants who have participated in such a study priory were used to the gas stove, which remained the same throughout the studies, but not to the light bulbs. In addition, expecting the light bulbs of the previous task, might interfere with getting used to the new

light bulb task. Secondly, we detected that the pathway of the switch of the light bulb was in fact longer than that of the gas stove. Therefore, the decision was made to shorten this switch (Figure 5). After this adjustment, the study could proceed. It is, however, of importance that participants in the main study will not have participated in a gas stove study prior to our study. Nevertheless, even if both tasks do turn out to be of significant different difficulty in the final sample, we can still measure whether the variation in difficulty of the stimuli affects the decrease in meta-memory confidence, detail and vividness, since our study also measures relevant checking with the light bulbs.

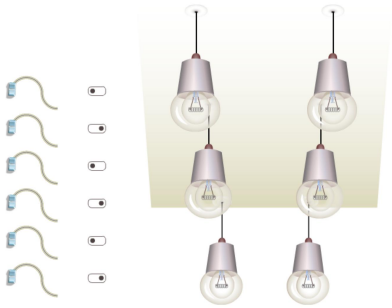


Figure 5. Representation of the light bulbs of the main study.

Method

Participants

The sample consisted of 27 males and 57 females. They were recruited at Utrecht University, but not all participants were currently studying at the University. The mean age was 21 years (range 15-29). Participants received either a small remuneration of three euros or college credit for their participation. None of the participants had taken part in a gas stove study prior to this study. In order to be able to compare our data to that of other studies, participants younger than 18 years were excluded (participant 20, 23 and 24) from analyses. This resulted in a final sample of 81 participants, of which 54 females and 27 males (*M*= 21.2).

Procedure and computer task

Participants were tested in a dimly lit and sound-attenuated laboratory room with a desk with a computer and a chair. They were seated behind the desk and were first asked to give their informed consent. If consent was given, they were once again asked whether they had participated in such a study before. To warrant for errors as the computer program was started, the researcher registered the participant number, age, gender, and whether or not one

had participated in a gas stove study prior to this study in the program. A modified version of the 3D checking computer task by van den Hout and Kindt (2003a), was used (OCD_run). In this task the light bulbs were presented in three rows of two light bulbs with switches (see Figure 5). The computer task started with a training phase during which participants could practice with turning the switches on and off by using the computer mouse. All instructions were presented on the screen. During this training phase participants were presented with one practice cycle of the light bulbs and one of the gas stove. First they had to turn these on, and next they were supposed to turn them off and were asked to check whether the stoves or bulbs were really off. Subsequently, the pre-test started. At pre- and post-test, first a diagram of six circles, of which three were yellow, was shown indicating which stoves or lights to turn on. They were then asked to turn the corresponding stoves or lights on. Next they had to turn these off, and finally they had to check whether the stoves or lights were correctly turned off. Following, they answered a short questionnaire consisting of different Visual Analogue Scales (VASs) on the computer, in order to measure the meta-memory. Research has shown that VASs provide valid estimates of mental states and are applicable in clinical research on various subjects (McCormack, Horne & Sheather, 1988).

Following, participants had to complete *20* checking trials of either light bulbs or gas stoves. In each trial, the diagram was presented to indicate which lights or stoves to turn on, off and check, which was randomly selected. The checking trials were either relevant or irrelevant. If the checking trial corresponded with the trial at pre- and post-test, it was considered relevant, if not, the checking trial was irrelevant. After the checking trials, the post-test was administered.

Assessments

Memory confidence. Participants were asked to indicate on a 100mm VAS, from ‘absolutely not confident’ to ‘absolutely confident’ how confident they were that their answer on the accuracy question was correct

Detail. Participants were asked to indicate how detailed their recollection of turning off the stove or bulbs in the last checking trial was on a 100mm VAS, running from ‘not detailed’ to ‘extremely detailed’.

Vividness. Participants were asked to indicate how vivid their recollection of turning off the stove or bulbs in the last checking trial was on a 100mm VAS, from ‘not vivid’ to ‘extremely vivid’.

Statistical analyses

The design of the study is a 2x2x2 design, since meta-memory will be assessed at two time points (pre- and post-test), two different stimuli are presented during the checking trial (gas stove and light bulbs), and there are two different conditions (relevant and irrelevant). This is presented in table 2. Results will be analysed with an ANOVA mixed model, since the meta-memory is a within-subjects measurement and the stimuli and conditions are measured between-subjects. A p-value below .05 is considered significant. In addition, one-sided 2 x 2 repeated measures ANOVAs will be performed to look at results for people who checked the gas stoves at pre- and post-test separately, in order to compare results to previous studies. Thereby, the same will be done for people who checked the lights at pre- and post-test, for additional information.

Table 2. *Conditions of the study*

Condition	**Pre-test**	**Checking trial**	**Post-test**	***Relevance***
1	Gas	Light	Gas	*Irrelevant*
2	Gas	Gas	Gas	*Relevant*
3	Light	Light	Light	*Relevant*
4	Light	Gas	Light	*Irrelevant*

Results

Time

A 20 x 2 x 2 mixed model ANOVA was performed using *Time* (check 1-20; a within factor), *Relevance* (relevant vs. irrelevant; a between factor) and *Stimuli* (Gas vs. Light; a between factor). There was a main effect of time ($F(21, 1617) = 23.35$, $p = .00$; $\eta^2 = .233$), which means that the duration of checking in the whole study population significantly reduced over time (Figure 6a). In addition, there was a significant main effect of group stimuli ($F(1, 77) = 20.60$, $p = .00$; $\eta^2 = .211$), meaning that the *mean* checking time was significantly lower in the gas stove than the light bulb checking trial (see different height in Figure 6b). In contrast, there was no main effect of relevance ($F(1, 77) = .29$, $p = .59$), which suggests the mean time did not differ between relevant and irrelevant checking. Mauchly's test indicated that the assumption of sphericity was not met, $X^2(189) = 546.65$, $p = .00$. Therefore, we used the Greenhouse-Geisser correction since this is the most robust. No significant interaction effect of time and stimuli was found ($F(21, 1617) = .90$, $p = .53$), which implies that the *change*

over time did not significantly differ between the gas stove and light bulbs (see similar course in Figure 6b). Also, no significant interaction effects of time and relevance ($F(21, 1617) = 2.35$, $p = .01$; $\eta^2 = .03$) or time, stimuli and relevance ($F(21, 1617) = 1.50$, $p = .13$) were found. In sum, checking light bulbs takes more time than checking gas stoves. However, the reduction of duration spent checking both stimuli is comparable over time.

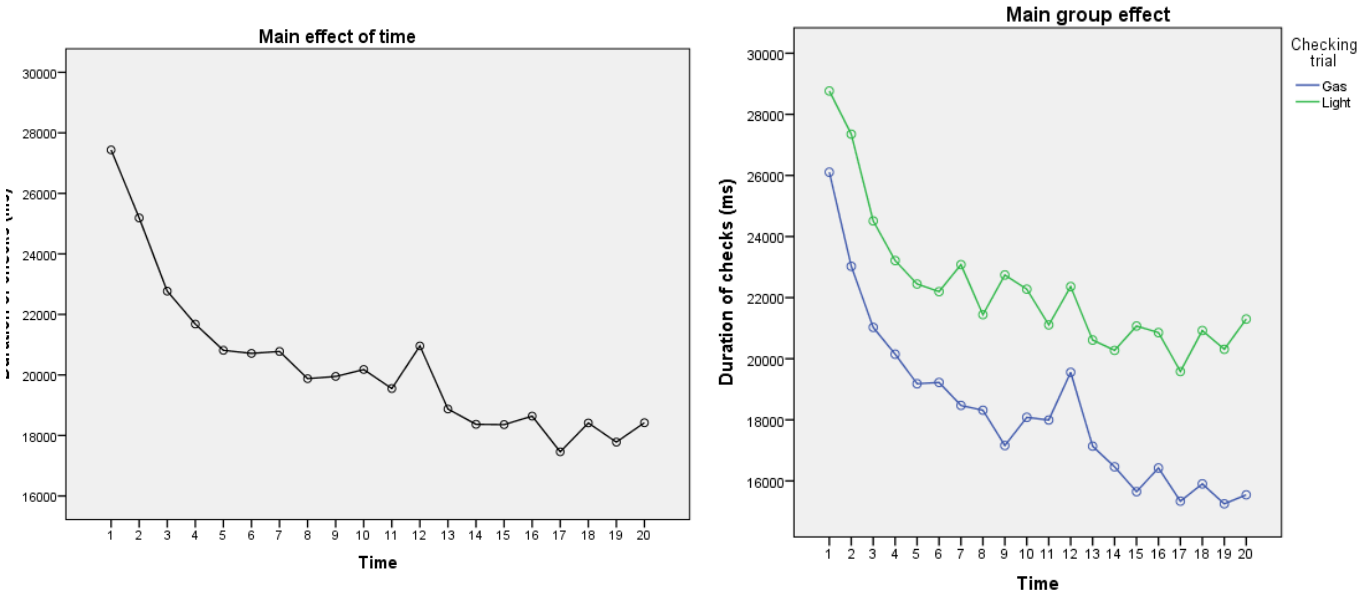


Figure 6. Time spent checking

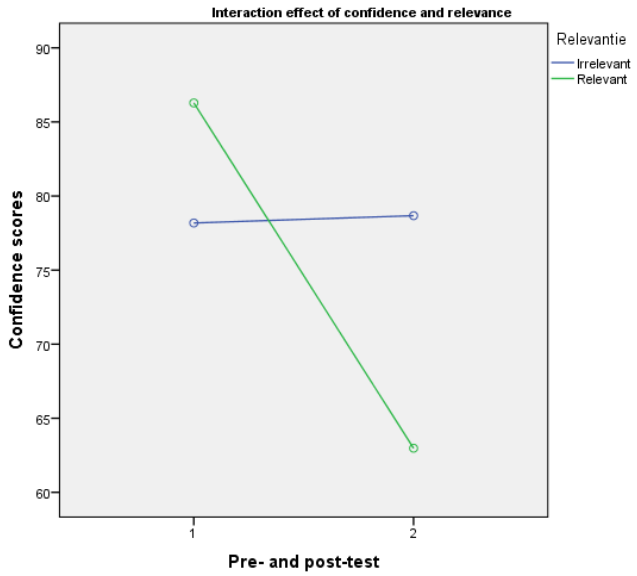
Confidence

A 2 x 2 x 2 ANOVA mixed model was performed using *Time* (confidence at pre-test vs. confidence at post-test; a within factor), *Relevance* (relevant vs. irrelevant; a between factor), and *Stimuli* (gas vs. light; a between factor). There was a main effect of time ($F(1, 77) = 6.93$, $p = .010$; $\eta^2 = .08$). Thus, in the whole study population, the confidence in memory reduced over time. Additionally, there was a significant interaction effect of time and relevance ($F(1, 77) = 7.54$, $p = .01$; $\eta^2 = .09$), indicating that, as we have hypothesized, the confidence scores declined significantly more in relevant checking compared to irrelevant checking (Figure 7a). There was no interaction effect for time and stimuli ($F(1, 77) = 2.21$, $p = .14$), meaning that the changes of confidence in memory over time did not differ depending on whether gas stoves or light bulbs were checked. Also the time, relevance and stimuli ($F(1, 77) = 1.44$, $p = .23$) interaction was not significant. This indicates that there was no difference between the light bulbs and gas stoves in the effect of relevant versus irrelevant checking on the memory confidence. In addition, there was no significant main effect for relevance ($F(1, 77) = .57$, $p =$

.45) and stimuli (F(1, 77) = 2.83, p = .10), which means that the mean confidence score was similar in the relevant versus irrelevant group and gas stove versus light bulb group, respectively. All in all, memory confidence decreases over time and this decrease is stronger for relevant checking

Following, only for people who had the gas stove stimuli during pre- and post-test, a one sided 2 x 2 repeated measures ANOVA was conducted with *Time* (confidence at pre-test vs. confidence at post-test; a within factor) and *Relevance* (relevant vs. irrelevant; a between factor). Again, a main effect of time was observed (F(1, 39) = 5.88, p = .0.10; η^2 = .13). Thus, confidence scores decreased in the whole population over time. The interaction effect of time and relevance was significant (F(1, 39) = 5.39, p = .01; η^2 = .12), showing that the reduction in confidence scores was significantly more in the relevant checking group compared to the irrelevant checking group (Figure 7b). There was no main effect of relevance (F(1, 39) = 1.52, p = .11), which means that on average the mean confidence score was not lower in the relevant versus the irrelevant group.

In addition, for people who had the light bulb stimuli during the pre- and post-test, a one sided 2 x 2 repeated measures ANOVA was also performed with *Time* (confidence at pre-test vs. confidence at post-test; a within factor) and *Relevance* (relevant vs. irrelevant; a between factor). There were no main effects of time (F(1, 38) = 1.24, p = .14) and relevance (F(1, 38) = .03, p = .43), indicating that the mean confidence score was not higher at pre-test versus post-test and not lower for relevant and irrelevant checking, respectively. Moreover, there was no interaction effect of time and relevance (F(1, 38) = 2.25, p = .07). The reduction in confidence of the memory was not more for relevant checking than irrelevant checking. These results do not support our expectation that the object that is checked does not affect the effects of relevant checking on the meta-memory. However, the interaction effect (p = .07) does approach significance and therefore shows a trend of higher reduction in confidence for relevant checking



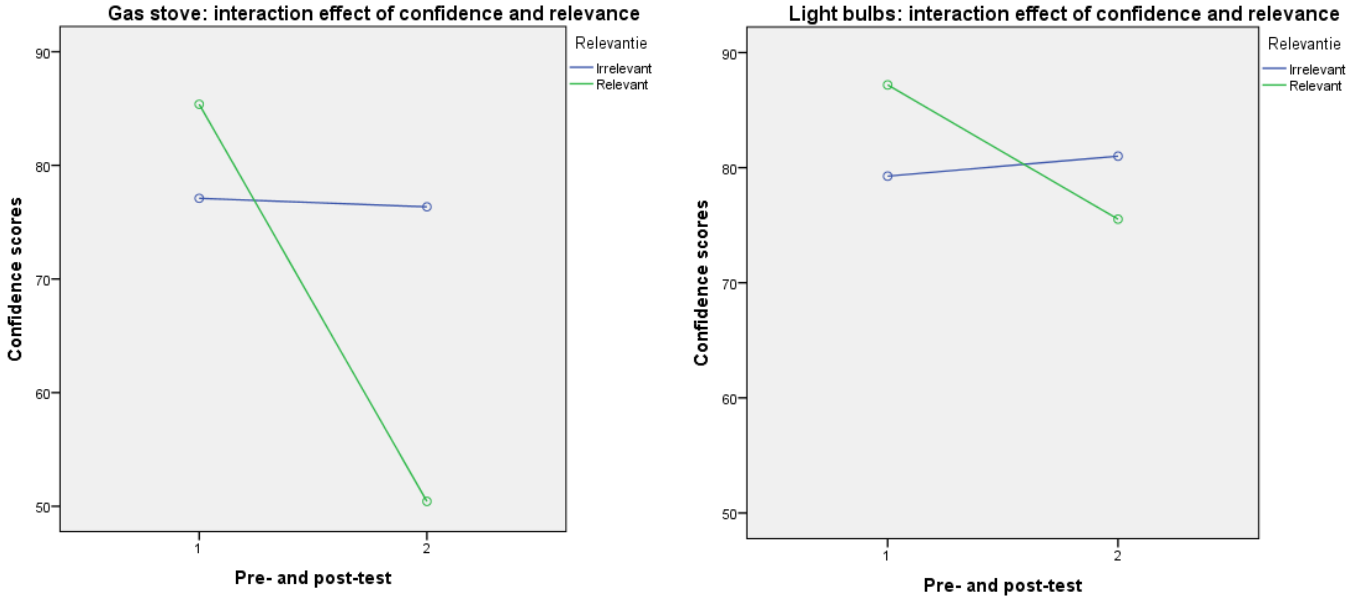


Figure 7. Memory confidence results.

Detail

A 2 x 2 x 2 ANOVA mixed model was performed. *Time* (detail at pre-test vs. detail at post-test; a within factor), *Stimuli* (gas vs light; a between factor) and *Relevance* (relevant vs. irrelevant; a between factor) were used. The main effect of time ($F(1, 77) = 14.05$, $p = .00$; $\eta^2 = .15$) was significant (Figure 8), meaning that the detail of the memory declined over time, in the whole study population. There was a significant interaction of time and relevance ($F(1, 77) = 6.64$, $p = .01$; $\eta^2 = .08$), showing that, in line with the hypothesis, relevant checking effects the detail of the memory more than irrelevant checking does. Also a significant time

and stimuli interaction was found ($F(1, 77) = 4.70$, $p = .033$, $\eta^2 = .06$), which indicates that the decline in detail over time is larger when checking gas stoves versus light bulbs. However, the time, relevance and stimuli interaction was not significant ($F(1, 77) = .26$, $p = .61$). This means that, as hypothesized, no difference was found between light bulbs and gas stoves in the effect of relevant versus irrelevant checking on the detail of the memory. There were no main effects of relevance ($F(1, 77) = 1.56$, $p = .22$) and stimuli ($F(1, 77) = .86$, $p = .86$), indicating that the mean detail score was similar in the relevant versus irrelevant group and gas stove versus light bulb group, respectively.

A one sided 2 x 2 repeated measures ANOVA was performed for people who had the gas stimuli during pre and post-test (like the studies before did). *Time* (detail at pre-test vs. detail at post-test; a within factor) and *Relevance* (relevant vs. irrelevant; a between factor) were used. This analysis demonstrated a main effect of time ($F(1, 39) = 12.78$, $p = .00$; $\eta^2 = .25$) and a main effect of relevance ($F(1, 39) = 7.41$, $p = .00$; $\eta^2 = .16$), thus the mean detail score was higher at pre-test versus post-test and lower for relevant checking than irrelevant checking, respectively. There was a significant interaction effect of time and relevance ($F(1, 39) = 3.47$, $p = .04$). Therefore, it appears that relevant checking leads to a stronger decline in detail than irrelevant checking.

A one sided 2 x 2 repeated measures ANOVA was performed for people who had the light stimuli at pre- and post-test. *Time* (detail at pre-test vs. detail at post-test; a within factor) and *Relevance* (relevant vs. irrelevant; a between factor) were used. No significant main effects were found for time ($F(1, 38) = 2.05$, $p = .08$) and relevance ($F(1, 38) = .25$, $p = .50$)). Thus, the mean detail was not higher at pre-test versus post-test and in the irrelevant group versus the relevant group, respectively. The interaction effect of time and relevance, however, was significant ($F(1, 38) = 3.51$, $p = .03$)). This means that, as expected, the decline in detail was stronger for relevant checking.

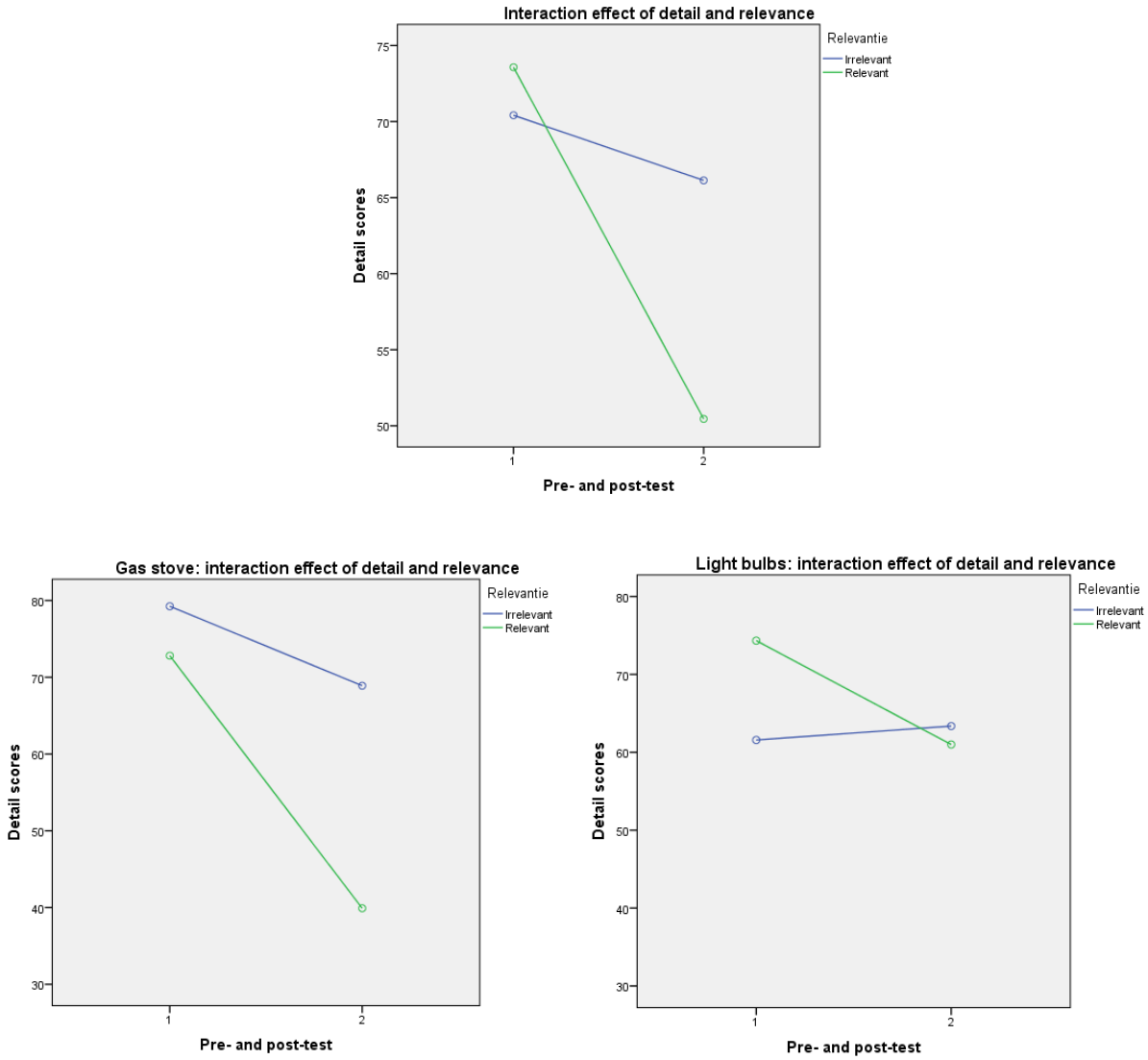


Figure 8. Memory detail results

Vividness

A 2 x 2 x 2 mixed model ANOVA was performed using *Time* (vividness at pre-test vs. vividness at post-test; a within factor), *Stimuli* (gas vs. light; a between factor) and *Relevance* (relevant vs. irrelevant; a between factor). There was a main effect of time ($F(1, 77) = 20.60$, $p = .00$; $\eta^2 = .21$), suggesting that in the whole study population, the vividness of memory declined over time. There was a significant interaction of time and relevance ($F(1, 77) = 7.88$, $p = .01$; $\eta^2 = .09$), meaning that the decline in vividness over time was steeper for relevant checking than for irrelevant checking, as expected. No interaction effect for time and stimuli was found ($F(1, 77) = 3.94$, $p = .05$), which suggests that the decline in vividness over time was comparable for light bulbs and gas stoves. In addition, the time, relevance and stimuli interaction was not significant ($F(1, 77) = .00$, $p = .97$). As hypothesized, this demonstrates

that there was no difference between light bulbs and gas stoves in the effect of relevant versus irrelevant checking on the vividness of the memory. No main effects were found for relevance and stimuli ($F(1, 77) = 2.03$, $p = .19$ and $F(1, 77) = .01$, $p = .91$, respectively). Thus, in the study population, the mean vividness score was similar in the relevant versus irrelevant group and gas stove versus light bulb group.

A one sided 2 x 2 repeated measures ANOVA was performed using *Time* (vividness at pre-test vs. vividness at post-test; a within factor) and *Relevance* (relevant vs. irrelevant; a between factor) for people who had the gas stimuli during the pre- and post-test. A main effect of time was observed ($F(1, 39) = 15.59$, $p = .00$; $\eta^2 = .29$), and of relevance ($F(1, 39) = 4.70$, $p = .02$; $\eta^2 = .11$), suggesting that the mean vividness score was higher at pre-test versus post-test and higher for irrelevant versus relevant checking, respectively. In addition, the interaction effect of time and relevance was significant ($F(1, 39) = 2.96$, $p = . 05$). Thus, the vividness of the memory is affected more when checking is relevant, whereas irrelevant checking leads to a smaller decline.

A one sided 2 x 2 repeated measures ANOVA was performed using *Time* (vividness at pre-test vs. vividness at post-test; a within factor) and *Relevance* (relevant vs. irrelevant; a between factor) for people who had the light stimuli during the pre- and post-test. There was a significant main effect of time ($F(1, 38) = 5.30$, $p = .01$; $\eta^2 = .12$), but not of relevance ($F(1, 38) = .00$, $p = .49$), meaning that the mean vividness score was higher at pre-test versus post-test, but not higher for irrelevant versus relevant checking. The interaction effect of time and relevance was significant ($F(1, 38) = 6.25$, $p = .01$; $\eta^2 = .14$). Thus, relevant checking leads to a larger fall in vividness of memory than does irrelevant checking.

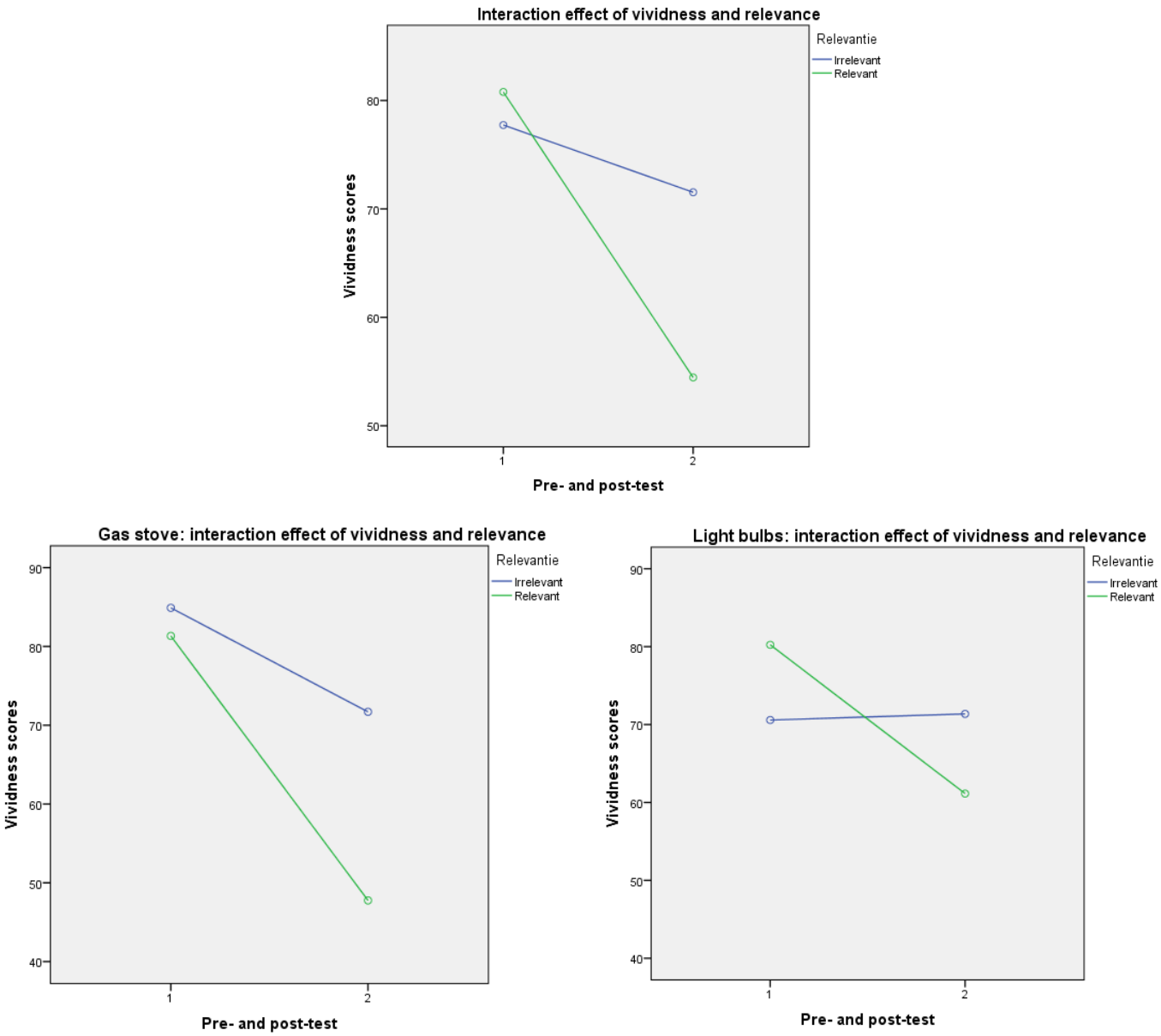


Figure 9. Memory vividness results

Effect sizes

Previous studies have not always reported the effect sizes of the effect of relevant checking on the meta-memory. Therefore, a mean of the reductions in the meta-memory variables, of studies that did rapport reductions, was calculated as shown in table 3. For comparison, the mean reductions of the meta-memory that were found in this study are presented in table 3 as well. Mean reductions of previous studies and the current study are comparable.

Table 3. *Mean reduction of meta-memory in previous studies (Radomsky, Gilchrist & Dussault, 2006; van den Hout & Kindt, 2004; van den Hout & Kindt, 2003a) and in the current study.*

Previous studies	Relevant	Irrelevant	**Current study**	Relevant	Irrelevant
Confidence	- 23.5	- 1.33	Confidence	- 24	0
Detail	- 27.17	- .5	Detail	- 24	- 4
Vividness	- 29.33	+ 1	Vividness	- 27	- 6

However, some studies did report the effect sizes, presented in table 4. If we compare these effect sizes to those found in this study, they are comparable.

Table 4. *Effect sizes of previous studies (Dek, van den Hout, Engelhard, Giele & Cath, 2015; Toffolo, van den Hout, Radomsky & Engelhard, 2015; Radomsky, Dugas, Alcolado & Lavoie, 2014) and of the current study.*

	Dek et al. (2015)	**Toffolo et al. (2015)**	**Radomsky et al. (2014): stove**	**Radomsky et al. (2014): sink**	**Current study**
Confidence	.07	.10	.25	.33	.09
Detail	-	.09	.18	.38	.08
Vividness	.07	.08	.16	.43	.09

Discussion

In the current study, unlike what was expected, the gas stove and light bulbs checking trial were still not equally difficult. The mean time was significantly lower in the gas stove checking trial than in the light bulb checking trial. In addition, as was hypothesized, repeated checking in the relevant checking trial reduced the meta-memory, affecting confidence, detail and vividness significantly.

Repeated checking affects the meta-memory. It leads to reductions in confidence, detail and vividness of memory. Moreover, the results of the subgroup analysis, generally support the idea that the type of object that is checked does not affect the effect that relevant checking has on the meta-memory. When looking solely at the people who checked gas stoves at pre- and post-test, as former studies have done, previous findings of the effects of relevant checking on the confidence, detail and vividness of the memory are replicated. In addition, the size of the effects found in our study replicate the effect sizes of previous studies (Table 4). Moreover, when we look specifically at the light bulb condition, the effects of relevant checking on detail and vividness of the memory were replicated as well. However,

this study did not show the effect of relevant checking on confidence of memory, when looking solely at people who were in the light bulb condition. Nevertheless, a trend in the reduction of confidence was shown. Most likely, the lack of finding a significant effect of relevant checking for confidence, can be explained by the fact that the subgroup analysis consisted of a low number of participants, which makes it harder to find significant effects.

More importantly, it should be concluded that the main goal of the study, namely creating two stimuli of equal difficulty, has not yet been accomplished. The light bulb trial proved more difficult than the gas stove trial in the new computer task. A possible explanation is that the light bulb trial in this study does not represent reality as the stoves do. People do not encounter light bulbs presented in three rows of two bulbs with S-shaped switches daily. They do, however, encounter the gas stoves as presented in the trial. Even though research by Dek (Dek, E.C.P., van den Hout, Giele, C.L. & Engelhard, 2014) for example, showed that checking abstract stimuli amounts to the same effects on the meta-memory, their study was conducted using abstract stimuli in both relevant and irrelevant checking. In addition, it could be possible that a learning effect occurs sooner if the object is recognizable. However, there is no research yet supporting this idea. Lastly, forgetting to turn off a gas stove could be assessed as more threatening than forgetting to turn off a light bulb. Tolin et al. (2001) acknowledged that OCD patients displayed a steeper decline in confidence about having seen unsafe objects. However, the control participants were not exposed to objects that were considered unsafe, and there is a real possibility that non-OCD participants show a comparable reduction in confidence if they were exposed to stimuli that are considered unsafe. Thus, the effects of familiarity on memory distrust could be larger for threatening materials. However, as discussed, the study by Dek et al. (2014) showed that the effects are also found with abstract stimuli. Additional research is needed to examine this. These reasons could account for the differences in time of repeatedly checking gas stoves versus light bulbs.

Further research and adaption of the computer task is necessary to create equal conditions. This research should focus on developing a light bulb trial that resembles reality and is not too simple at the same time. An optional improvement could be changing the switches of the light bulb trial in turning knobs as well, like the ones used for dimming lights in real life. This way the knobs would resemble reality and be as much alike the ones of the gas stove as possible. In this case, one could argue that this would make both stimuli very similar. However, this does not have to be a problem, since it is desirable that both stimuli are as much alike as possible in order to be of equal difficulty whilst still accounting for an effect of relevance on the meta-memory. After all, a successful control condition demonstrates that

the relation of variable x to variable y is not present if variable x is not present (Boring, 1969). In order to achieve this, both conditions should be as similar as possible, except from the one variable that is researched, in this case the relevance of checking. A study including turning knobs for the light bulbs would provide information whether or not the effect of relevant checking in comparison with irrelevant checking occurs because of the difference in movement between the checking trial and the pre- and post-test in the irrelevant condition, or whether it is the stimuli in itself. Thereby, it should be considered if the presentation of the light bulbs in three rows of two is realistic and whether there are alternatives for this. Presenting the light bulbs further apart, like lights are usually administered in people's houses might be recommended. Finally, an entirely different approach might be considered like a whole new object for the control condition of irrelevant checking in order to also account for the possible effect of the threat of the stimuli. Preferably, one that is of equal difficulty and threat as a gas stove but still realistic, like locks perhaps, which would also account for the possible effect of the threat of the stimuli. However, this would make comparison to previous studies more difficult.

The current study has both strengths and weaknesses. First of all, this study has a population that was much alike the ones used in the other studies, which makes comparison possible. However, this led to a population of healthy undergraduates only, which might limit generalization to other populations. Nevertheless, since prior studies have found the same results in patient populations and for populations of different ages and levels of education, there is little reason to doubt generalizability of our results. In addition, virtual checking occurs in the absence of real threat, which leaves the question whether these metacognitive declines associated with repeated checking behaviour were affected by the presence of real perceived threat. Finally, participants were not asked for their opinion of the stimuli they encountered. This could have provided information about the perceived difficulty of the gas stoves and light bulbs and could have provided indications for improving the stimuli to make them equal.

To conclude, the present study has shown that the adaptions to the computer task by van den Hout and Kindt (2003a), did not sufficiently provide a new computer task with an experimental and control condition of equal difficulty. Nevertheless, this study provides information about how the computer task should be adjusted in order to reach this goal. Moreover, the study has successfully replicated previous findings that relevant checking affects the meta-memory. Confidence in memory, detail of the memory, and vividness of the memory are all reduced after relevant checking. Lastly, the results of the study gives

additional reason to believe that the same results would be found if the relevant condition consisted of checking lights instead of the gas stoves.

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