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Induction of conditioned avoidance via mental imagery

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ABSTRACT

There is a growing interest on how mental imagery may be involved in the onset and maintenance of anxiety-related disorders. Here, we used an experimental design to investigate whether a key symptom across anxiety-related disorders, namely avoidance, can be induced via mental imagery. Healthy participants first learned that one neutral stimulus (A) was associated with a mild electric shock and two other neutral stimuli (B and C) were not. They then learned to cancel the shock when A was presented, by pressing a button on a keyboard ('behavioral avoidance'). Next, they were asked to *imagine* that stimulus B was followed by the shock (i.e., without actual B or shock presentations; Experiment 1; $N = 66$) or they were shown B and asked to imagine the shock (i.e., without actual shock presentations; Experiment 2; $N = 60$). Finally, in the test phase, they were shown each of the three stimuli (without the shock) and given the opportunity to make the avoidance response. Results showed that participants tended to avoid B in the test phase in Experiment 1, even though it had never been presented with the shock but not in Experiment 2. We discuss how the findings may explain the acquisition of avoidance in the presentation of innocuousstimuli across anxiety-related disorders.

1. Induction of conditioned avoidance via mental imagery

There is a growing interest on the role of mental imagery in anxiety- and stress-related disorders and how it can be involved in the etiology, maintenance, and treatment of mental disorders (e.g., Engelhard, McNally, & van Schie, 2019; Hirsch & Holmes, 2007; Holmes & Mathews, 2010; Patel et al., 2007). To illustrate, Morina, Deeprose, Pusowski, Schmid, and Holmes, (2011) showed that patients with anxiety disorders are more able to generate imagery for prospective negative scenarios compared to patients with major depression or healthy controls. Despite these insights, we lack important knowledge about the basic learning mechanisms of how mental imagery could probably lead to specific symptoms of anxiety-related disorders.

In order to shed light on the basic learning mechanisms of the onset of anxiety-related disorders, conditioning procedures are often employed. In such procedures, a neutral stimulus (e.g., picture of a square; conditioned stimulus or CS) is associated with an aversive stimulus (e.g., an electric shock; Unconditioned stimulus or US) so that now the CS will evoke fear reactions (e.g., increased fear; conditioned responses or CRs) to the CS alone. Although conditioning protocols typically involve the *direct experience* of CS and the US, there is evidence that the acquisition, extinction, and maintenance of CRs can also be achieved via *imagining* the CR, the US, and their associations (for reviews see Dadds, Bovbjerg, Redd, & Cutmore, 1997; Mertens, Krypotos, & Engelhard, 2020). To illustrate, Jones and Davey (1990) have shown that after undergoing a differential conditioning procedure, in which one CS (i.e., CS+) was paired with a shock whereas another CS (i.e., CS-) was not, participants who were asked to mentally rehearse the shock after the end of the procedure, retained higher CRs (i.e., elevated skin conductance) compared to participants who mentally rehearsed a neutral event (i.e., a cat meowing). These results suggest that US imagery preserves CRs. In another fear conditioning study, Dibbets, Poort, and Arntz (2012) showed that adding an imagery rescripting procedure, in which participants devalued the US after fear acquisition, reduced return of fear induced by a different context, compared to a control procedure of mere positive imagery. More recently, Mueller, Sperl, and Panitz (2020) showed that fear responses (e.g., startle reactions) to neutral faces (i.e., CSs) were evoked by just combining these CSs with neutral objects that were previously paired with aversive mental images. Collectively, experimental findings demonstrate that conditioning procedures can be useful to test whether mental imagery is involved in the onset and maintenance of learned fear.

Despite these insights, most studies including mental imagery in conditioning procedures have used only subjective and physiological CRs (Mertens et al., 2020). To our knowledge, no study so far has attempted to test whether mental imagery may also result in another key symptom of anxiety-related and stress-related disorders; namely behavioral avoidance (American Psychiatric Association, 2013).

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Experimental evidence suggests that behavioral avoidance maintains anxiety (e.g., Lovibond, Mitchell, Minard, Brady, & Menzies, 2009) and may trigger a return of fear after extinction took place (van Uijen, Leer, & Engelhard, 2018; Vervliet & Indekeu, 2015). This is why a thick body of literature has focused on finding the factors involved in the onset of avoidance. Previous laboratory research has shown that conditioned avoidance can not only be acquired via direct experience, but also by verbal instructions (Mertens, Boddez, Sevenster, Engelhard, & De Houwer, 2018), or vicarious learning (Lindström & Olsson, 2015). Importantly, if avoidance can only be induced via these pathways, it remains unclear why patients with anxiety symptomatology avoid innocuous stimuli, without recalling any direct or indirect (i.e., via verbal instruction or social observation) associations between these stimuli and an aversive (i.e., now the phobic) event (Rachman, 1977). This could be explained by considering that mental imagery may also result in behavioral avoidance.

As such, the goal of the present research was to examine whether avoidance towards CSs can be established by mental imagery. We conducted two experiments. The aim of experiment 1 was to test whether avoidance towards a stimulus that was never paired with an aversive event can be established by asking participants to imagine that stimulus, the aversive event, and their association. First, participants completed a differential Pavlovian fear procedure, in which one neutral CS (A+) was followed by a mild electric shock, whereas two other neutral stimuli (B- and C-) were not followed by a shock. Then, and in line with previous studies (Krypotos, Vervliet, & Engelhard, 2018), they completed an instrumental procedure, in which A+ and C- were presented. Participants could avoid the shock presentation by pressing the space bar on a computer keyboard. Next, they completed an imagery phase, and were assigned to one of two groups. A *Negative imagery* group was asked to imagine that stimulus B was followed by the shock and their responses to it (i.e., without actual B or shock presentations, whereas a *Neutral imagery* group was asked to imagine that B- was followed by a neutral tone. Finally, in the test phase, each CS was shown and participants were given the opportunity to make an avoidance response (i.e., space-bar press). They were also asked to rate their shock expectancy and fear.

The goal of Experiment 2 was to test whether avoidance can be established when participants rehearsed the shock, in the presence of the CS (i.e., during CS presentation). Such a procedure is similar to previous imagery studies (e.g., Jones & Davey, 1990) and is simpler compared to the procedure of Experiment 1. As such, in Experiment 2 the Negative imagery group was asked to imagine a shock (and their reactions to it) whenever B- was presented, whereas the Neutral imagery group was asked to imagine a neutral tone (and their reactions to it) whenever B- was presented. In each experiment, we expected more avoidance responses to B- for the Negative imagery group compared to the Neutral imagery group.

2. Experiment 1

2.1. Methods

2.1.1. Participants

A power analysis with G*Power, showed that for an effect size of $f = 0.20$ (medium to small), for 3 measurements (the 3 CSs) and 2 groups, an alpha level of 0.05, a power of .80, a correlation between repeated measures of 0.5, a non-sphericity correction ε of 1, and the G*Power 3.0 as the effect size specification, we needed at least 42 participants. In order to account for potential missing data, we recruited 66 individuals, which allowed us to detect an effect size of $f = 0.18$.

2.1.2. Stimuli

Sixty-six individuals participated in Experiment 1 (49 females; 17 males; mean age = 22.27 years, SD = 3.63). The data of one additional participant were removed from the analyses due to him/her stopping before the end of the experiment. Participants were assigned on order of appearance to the *Negative imagery* ($n = 34$) or the *Neutral imagery* ($n = 32$) group. Each participant was interviewed prior to their participation to evaluate exclusion criteria (i.e., any psychiatric disorder, colorblindness, hearing problems, pregnancy, and medication that could affect their attention, reactions, or memory, all assessed by self-report).

CSs were three coloured squares (i.e., green, orange, or blue) of 100 × 100 pixels. Which CS served as A+ and C- was determined randomly, but the blue square always served as B-. The US was an electric shock delivered via a Coulbourn Transcutaneous Aversive Finger Stimulator (E13-22) with a 9-V dry cell battery attached to an adjustable step-up transformer. The shock level was set individually to a level that is definitely unpleasant but not painful (Fonteyne, Vervliet, Hermans, Baeyens, & Vansteenwegen, 2009).

2.1.3. Measures

US-expectancy ratings were collected during all CS presentations in all conditioning phases using a 10-point scale ranging from −5 (*certainly no electric stimulus*), to 0 (*uncertain*), to 5 (*certainly an electric stimulus*). CS-fear was measured using a 10-point scale ranging from −5 (*not fearful at all*) to 5 (*extremely fearful*). Participants also rated US-unpleasantness from −5 (*too unpleasant*), to (*neutral*), to 5 (*pleasant*), US-intensity (*weak*, *moderate*, *intense*, *enormous*, *unbearable*), and US-startlingness (*not*, *light*, *moderate*, *strong*, *too strong*). They reported their motivation to complete the computer task and to fill in the questionnaire on two scales ranging from −5 (*very low*) to 5 (*very high*). Finally, they completed the neuroticism portion of the Eysenck Personality Questionnaire (EPQ-N) (H. J. Eysenck & Eysenck, 1975; see Lommen, Engelhard, and van den Hout (2010) for a study showing that avoidance generalization is modulated by levels of neuroticism) and the Betts' Questionnaire Upon Mental Imagery (QMI) (Sheehan, 1967).

Table 1
Overview of the experimental design used in Experiment 1 for both groups. The numbers within the brackets denote the number of trials for each stimulus.

	Pavlovian Phase	Instrumental Phase	Imagery Phase	Test Phase
Negative Imagery	A+ (3) B-(3) C-(3)	A*+/− (5) A+(1) C*-(5) C-(1)	Imagine B is followed by a US	A*-? (4) B*-? (4) C*-? (4)
Neutral Imagery	A+ (3) B-(3) C-(3)	A*+/− (5) A+(1) C*-(5) C-(1)	Imagine B is followed by a tone	A*-? (4) B*-? (4) C*-? (4)

Note. +: US presentation; -: US absence; +/−: US presentation is conditional to whether participants pressed the button or not. *: Avoidance response availability.

2.1.4. Procedure

A schematic overview of the procedure is shown on Table 1. The basic conditioning design used by Lovibond et al. (2009) and Engelhard, van Uijen, van Seters, and Velu (2015) was modified to the purpose of this study, for instance, by including an imagery phase.

First, participants read the information brochure and signed the consent form. Then the shock electrodes were fitted on participants' middle of the index and middle finger of their non-dominant hands.

Participants were instructed, both verbally and on-screen, that they would encounter different stimuli, some of which would be followed by a shock. They were also instructed that they should provide their US-expectancy by using the US-expectancy scale that would be presented on the bottom of the screen. Then, the Pavlovian phase started.

Each conditioning trial started with the presentation of one of the three CSs for 5 s. Then, the US-expectancy scale was presented on the bottom of the screen for 5 s. The Pavlovian Phase consisted of three presentations of A+, B-, and C-. In case of A+, the shock was presented immediately after the end of the trial. In order to keep the experiment short, and given that no physiological measures were included, the inter-trial intervals were short (2, 3, or 4 s) and were presented randomly. The order of all trials, throughout the task, was pseudorandom with no more than 2 presentations of the same type of trial.

Before the beginning of the Instrumental phase, participants were informed that they could avoid the shock by pressing the space bar during the first 5 s of the CS presentation. Instructions stressed that they had to press the button only if they expected a shock and not during the presentation of every CS. The trial structure was the same as in the Pavlovian phase. Performing the avoidance response before rating the US-expectancy is in line with previous avoidance studies (e.g., Lovibond et al., 2009). Then the Instrumental phase started, in which participants encountered 5 presentations of stimulus A or C while the avoidance response was available. Importantly, to ensure that participants understood that A was still followed by the US and C was not, we also presented both A and C once without the availability of the avoidance response. This is in line with previous studies (Engelhard et al., 2015; Lovibond et al., 2009).

Following the instrumental phase, participants were randomly assigned to the *Negative imagery* or the *Neutral imagery* group. The *Negative imagery* group listened to the following text though headphones (translated from Dutch):

> "*Imagine this situation as if it is happening now. Imagine that you see different squares on the screen. At some point, you see the blue square. You rate how much you expect the electric stimulation. At the end of the presentation of the blue square, you feel the shock on your hand. You are frightened, your heart rate increases, and your hands begin to sweat. Keep the image of this situation as vividly as possible in your imagination. Concentrate on the sensations you feel. Can you see the square? Do you feel the shock? Take your time to imagine it. Press the space bar when you have imagined the situation as vividly and detailed as possible.*"

The script for the *Neutral imagery* group was (also translated from Dutch):

> "Imagine this situation as if it is happening now. Imagine that you see different squares on the screen. At some point, you see the blue square. You rate how much you expect the electric stimulation. At the end of the presentation of the blue square, you hear a neutral tone. You feel calm and not scared at all, and you continue to breathe normally. Imagine this situation as vividly as possibly. Concentrate on the sensations that you feel. Do you hear the tone? Take your time to imagine the situation. Press the space bar when you have imagined the situation as vividly and detailed as possible."

Then the experiment continued with the Test phase, in which participants saw four unreinforced presentations of A, B, and C. They were told that the experiment would continue and they would see the pictures of squares. After the experimental task, participants were asked to rate their fear about the CS (i.e., the fear ratings), filled out the EPQ and QMI, and rated their US evaluation.

2.1.5. Statistical analyses

All questionnaires, the US-ratings, the CS ratings (i.e., fear ratings and US-expectancies), and background characteristics were analysed using separate independent samples *t*-tests, except for sex, which was analysed using a chi-square test. US-expectancy characteristics were analysed separately for each phase using 3 (CS: A, B, C) x 2 (Group: *Negative imagery* vs. *Neutral imagery*) xTrial repeated measures Analyses of Variance (ANOVAs), with 2 within subject factors (CS, Trial) and 1 between subject factor (Group). The levels of the Trial factor were adjusted according to the number of trials of each phase (see Table 1). In case the sphericity was violated, we used the Greenhouse-Geisser Corrections. In case of significant interactions, we followed-up the results with post-hoc tests with Bonferroni correction. In case of multiple comparisons, we used the Holm's post-hoc tests within JASP, with the corresponding *p*-values denoted as *pHolm*.

Before analysing the avoidance data, mean proportions of each stimulus were computed separately for the Instrumental and the Test phase. Then, we ran separate 3 (CS: A, B, C) x 2 (Group: *Negative imagery* vs. *Neutral imagery*) repeated measures ANOVAs.

As in previous studies (e.g., Krypotos & Engelhard, 2018), we conducted our analyses within both a Null-Hypothesis Significance Testing and a Bayesian framework. For the Bayesian analyses, we computed Bayes factors, the Bayesian alternative to a Null-Hypothesis Significance Testing. Bayes factors quantify the amount of evidence that the data provide for one of two hypotheses, which are the alternative and the null hypotheses in this study. The larger the Bayes factor, the more relative evidence there is for one hypothesis compared to the other. Here, we denote Bayes factors that quantify evidence under the experimental hypothesis, relative to the null hypothesis, with BF_{10}, and the reverse with BF_{01} (see Krypotos, Blanken, Arnaudova, Matzke, & Beckers, (2017) for a basic introduction of Bayesian statistics for psychopathology research). In case of the Bayesian post-hoc tests, the letter "U" next to the Bayes factor indicates that they are uncorrected as mentioned within JASP.

It is recommended that researchers reporting Bayesian results refer to their statistical models and selection of prior distributions (i.e., distributions that quantify the researcher's current knowledge before seeing the data) (Krypotos, Klugkist, Mertens, & Engelhard, 2019). For the Bayesian analyses, we used the validated models described in Rouder and Morey (2012) and Rouder, Speckman, Sun, Morey, and Iverson (2009). All models were run using JASP (Love et al., 2015). For the alternative hypotheses, we used a Cauchy distribution with mean at zero and a scale factor of 0.707 (default option) and 1. The direction of the results remain the same when the different scale factors were used, so we present the results using the former scale factor. For the Bayesian post-hoc tests, we use the default post-hoc models in JASP. We do not report Bayes factors for post-hoc tests when there is an interaction, this a matter of further development in the field (Wagenmakers et al., 2018). For the Bayesian χ^2 tests, we used the default models in JASP. In the spirit of open-science (Krypotos et al., 2019), all data and materials are available at: https://osf.io/mbr87/.

3. Results

3.1. Demographics and self-reports

No between group differences were detected in terms of age, t (61.14) = −0.085, p = 0.932, *Cohen's d* = - 0.021, BF_{01} = 3.952 or sex, χ^2 (1) = 0.891, BF_{01} *independent multinomial* = 2.946.

No between-group differences were found regarding the QMI scores, t(63.79) = −1.246, p = 0.217, *Cohen's d* = −0.307, BF_{01} = 2.055, EPQ-N, t (62.54) = −0.494, p = 0.62, BF_{01} = 3.577, US- unpleasantness, t(53.57) = 0.495, p = 0.623, *Cohen's d* = 0.121,

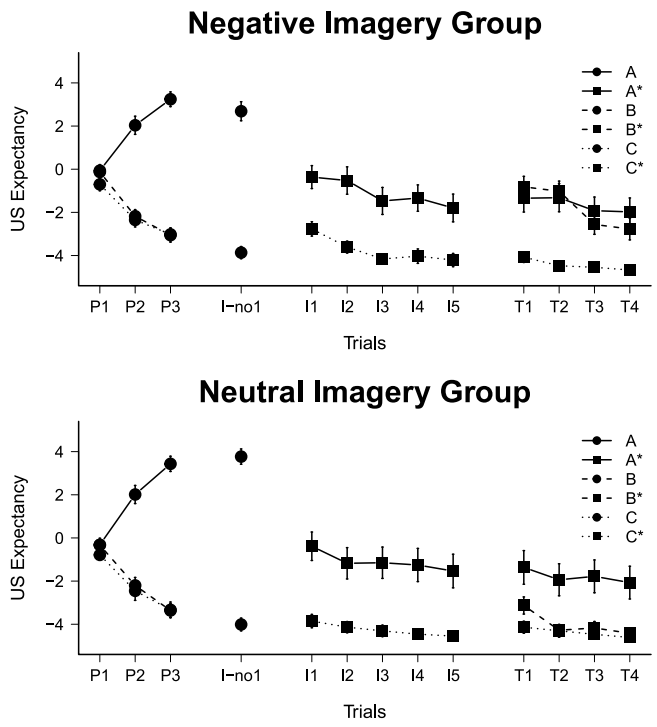

Fig. 1. Experiment 1: Mean US-expectancy ratings across the whole experiment for all CSs for the Negative Imagery Group (top panel) and the Neutral Imagery Group (bottom panel).

BF_{01} = 3.582, US-intensity, $t(63.31) = 1.821$, $p = 0.073$, *Cohen's* d = 0.449, BF_{01} = 0.980, or US-startlingness, $t(63.90) = 1.188$, $p = 0.239$, *Cohen's d* = 0.293, BF_{01} = 2.181. Finally, no between group differences were detected for the motivation to complete the task, $t(62.07) = 0.11$, $p = 0.913$, *Cohen's d* = 0.027, BF_{01} = 3.944, or to fill out the questionnaires, $t(62.35) = -0.154$, $p = 0.878$, *Cohen's d* = −0.038, BF_{01} = 3.924. For detailed scores across groups, please see the Supplementary materials.

3.2. US-expectancies

Mean US-expectancies across all phases are shown in Fig. 1. Across the Pavlovian phase, participants reported different US-expectancies for the CSs, CS x Trial $F(2.50, 159.68) = 87.786$, $p < 0.001$, $\eta_p^2 = 0.587$, $BF_{10} = 6.726 \times 10^{43}$, which was similar across groups, CS x Trial x Group, $F(2.50, 159.68) = 0.238$, $p = 0.835$, $\eta_p^2 = 0.004$, $BF_{01} = 41.666$. Post-hoc analyses showed that participants reported higher US-expectancies for A than B, $pHolm < 0.001$, $BF_{10}U = 1.193 \times 10^{23}$ and A than C, $pHolm < 0.001$, $BF_{10}U = 3.946 \times 10^{27}$. These results indicate successful acquisition.

In the instrumental phase, participants also reported higher US-expectancies for A compared to C, CS $F(1, 64.) = 46.044$, $p < 0.001$, $\eta_p^2 = 0.418$, $BF_{10} = 5.596 \times 10^{13}$, which did not differ as a function of trial, CS x Trial, $F(2.61, 167.14)$, $p = 0.183$, $BF_{01} = 61.815$, or group, CS x Group, $F(2.61, 167.14) = 0.620$, $p = 0.581$, $\eta_p^2 = 0.010$, $BF_{01} = 276220.492$.

As predicted, between group differences were reported in the Test phase, CS x Group, $F(1.35, 86.69) = 4.834$, $p = 0.021$, $\eta_p^2 = 0.070$, $BF_{10} = 9.122 \times 10^6$. Although there was a significant interaction with Group, CS x Trial x Group, $F(3.73, 238.80) = 2.69$, $p = 0.035$, $\eta_p^2 = 0.040$, the relevant Bayes factor provided strong support from the null hypothesis compared to the alternative one $BF_{01} = 45.456$. Testing US-expectancies for stimulus B in the Test phase showed that there were between group differences, $pHolm < 0.001$, $BF_{10} = 553.972$, with participants in the *Negative imagery* group reporting higher US-expectancies, *Mean* = −1.792, compared to the *Neutral imagery* group, *Mean* = −4.00. Post-hoc tests showed that no-between group differences arose in the test phase for stimulus A, $pHolm = 1$, or C, $pHolm = 1$, but only for B, $pHolm = 0.005$. Collectively, the results indicate that negative imagery, compared to neutral imagery, resulted in elevated US-expectancies to stimulus B.

3.3. Avoidance

Fig. 2, top and middle panel, shows mean proportions of avoidance reactions for the instrumental (left) and the test phase (right).

Results showed that during the instrumental phase, participants learnt to press the space bar more often during the presentation of the A compared to C, CS $F(1, 64) = 683.690$, $p < 0.001$, $\eta_p^2 = 0.914$, $BF_{10} = 2.045 \times 10^{51}$, in both groups, CS x Group, $F(1, 64) = 0.96$, $p = 0.33$, $\eta_p^2 = 0.015$, $BF_{01} = 2.611$.

Between group differences were detected in the test phase, CS x Group, $F(1.66, 105.98) = 11.613$, $p < 0.001$, $\eta_p^2 = 0.154$, $BF_{10} = 2353.584$. Follow up *t*-tests, as well as the respective post-hoc tests, for B and C showed that although the *Negative imagery* group pressed the space bar more often during the presentation of the B than C, $t(33.71) = -3.741$, $p < 0.001$, *Cohen's d* = −0.642, $BF_{10} = 44.062$, $pHolm < 0.001$, this was not the case for the *Neutral Imagery* group, $t(31) = -1.00$, $p = 0.325$, *Cohen's d* = −0.177, $BF_{01} = 3.347$, $pHolm = 1$. Collectively, the results indicate that negative imagery, relative to neutral imagery, resulted in more conditioned avoidance.

3.4. Fear ratings

Regarding the CS-fear ratings, between group differences were detected, CS x Group, $F(1.67, 106.62) = 6.90$, $p = 0.003$, $\eta_p^2 = 0.097$, $BF_{10} = 44.316$. Post-hoc tests showed that in accordance with the avoidance responses and the US-expectancies, participants in the *Negative imagery* group reported more fear for B than for C, $pHolm < 0.001$, than those of the *Neutral imagery* group, $pHolm = 0.493$. Collectively, the *Negative imagery* group reported higher fear ratings for B, compared to C, than the *Neutral imagery* group.

3.5. Discussion

In this first experiment, we tested whether conditioned avoidance and subjective CRs (US-expectancies and fear ratings) can be acquired via the imagery of CS-US associations. Confirming our hypotheses, results showed that participants in the *Negative imagery* group, who imagined the association between a safe CS (i.e, B) and a US, exhibited higher avoidance rates and subjective fear towards the control stimulus (i.e., the C), than the control group (i.e., *Neutral imagery* group).

In Experiment 2, we attempted to replicate and extend the findings of Experiment 1. Specifically, in Experiment 1, we attempted to test whether mental imagery of the CS, the US, and their associations are sufficient for the installation of conditioned avoidance. In Experiment 2, we attempted to test whether simple mental rehearsal of the US is sufficient for establishing avoidance. Such a procedure was sufficient for maintaining conditioned responses in prior research (e.g., see Jones & Davey, 1990), but it still remains unknown whether similar findings arise for avoidance responses. As such, in Experiment 2, we instructed participants to imagine the US and their reactions to it (or a neutral tone in the control condition), whenever B- was actually presented, without giving them explicit instructions about the CS-US contingencies. By testing this question, we could clarify whether imagery of the CS, US, and CS-US contingency is required for the induction of explicit avoidance or whether just US rehearsal, in the presence of the CS, as in Jones and Davey (1990), is sufficient to install avoidance.

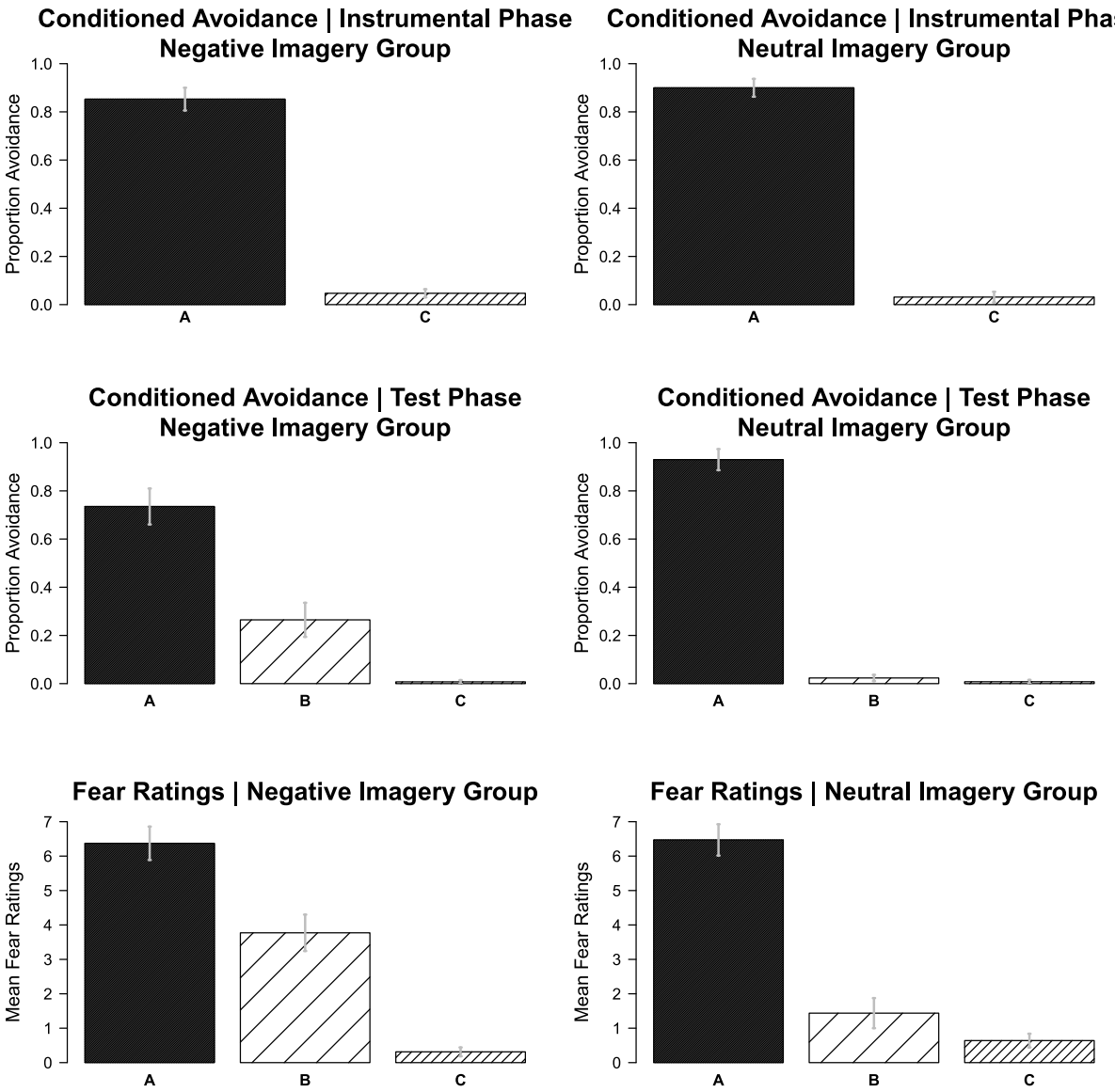

Fig. 2. Experiment 1: Mean proportion of avoidance responses for each CS and for each group during the instrumental (top) and test phase (middle panel). Fear ratings for each CS and for each group (bottom panel).

4. Experiment 2

4.1. Methods

4.1.1. Participants

There were 62 participants, but two of them discontinued the experiment, so their data were removed from further analyses. The remaining 60 participants (37 females, 23 males; mean age = 22.52 years, SD = 2.40) were randomly assigned to one of two groups: *Negative imagery* (N = 30) or *Neutral imagery* (N = 30). All participants were screened using the same criteria as in Experiment 1.

4.1.2. Materials

The same stimuli and questionnaires were used as in the first experiment, but we added the *Vividness* scale, on which participants rated the vividness of each mental image (see below) using a scale from 1 (*not at all*) to 9 (*as vividly as a real image*), and the trait (STAI-T) and state (STAI-S) scales of the Spielberger state-trait anxiety inventory (Ploeg, 2000; Spielberger, Gorsuch, & Lushene, 1970). The STAI-S was completed both at the beginning and the end of the main experiment.

The procedure (see Table 2), including trial sequence and timing,

Table 2
Schematic overview of the experimental design used in Experiment 2 for both groups. The numbers within the brackets denote the number of trials for each stimulus.

	Pavlovian Phase	Instrumental Phase	Imagery Phase	Test Phase
Negative Imagery	A+ (6)	A*+/− (6)	Imagine the US when you see B	A*-? (4)
	B-(6)	A+(2)		B*-? (4)
	C-(6)	C*-(6)		C*-? (4)
		C-(2)		
Neutral Imagery	A+ (6)	A*+/− (6)	Imagine a tone when you see B	A*-? (4)
	B-(6)	A+(2)	B- (8)	B*-? (4)
	C-(6)	C*-(6)		C*-? (4)
		C-(2)		

Note. +: US presentation; -: US absence; +/−: US presentation is conditional to whether participants pressed the button or not. *: Avoidance response availability.

was identical to the procedure of Experiment 1, except for the following changes: (1) we collected CS-fear ratings at the beginning and the end of the experiment, (2) we slightly increased the number of trials to get stronger conditioning effects, and (3) scripts for the imagery phase were adjusted to the purpose of Experiment 2.

For the *Negative imagery* group, the script mentioned the following (translated from Dutch):

> "*Whenever you see a blue square in the next phase, imagine a shock and your reactions to it, like the shock you received in the first phase of the experiment. For example, imagine that you receive a shock on your fingers. As a result of it your heart rate increases, and your hands begin to sweat. So Whenever you see a blue square in the next phase, visualize this situation and the accompanying sensations as vividly as possible.*"

Accordingly, the script for *Neutral imagery* was the following (translated from Dutch):

> "*Whenever you see the blue square in the next phase, imagine that you hear a neutral tone. Imagine also your reactions to this tone, as vividly as possible. For example, imagine that whenever you hear a tone that you feel calm and not anxious, and that you breath normally. So when you see the blue square in the next phase, visualize that you are in this situation as vividly as possible.*"

The blue square was then presented for 6 times. At the end of this phase, participants completed the vividness scale.

4.1.3. Statistical analyses

Statistical analyses were identical to those of Experiment 1, except: a) for all repeated measures ANOVAs, we changed the levels of the trial factor (see Table 2), because more trials were used in this experiment, and b) for the fear ratings, we used a 3 (CS: A, B, C) x 2 (Time: Beginning vs. End) repeated measures ANOVA.

5. Results

5.1. Demographics and self-reports

No between group differences were detected in terms of age, $t(53.73) = 1.35$, $p = 0.182$, *Cohen's d* $= 0.349$, $BF_{01} = 1.776$, or sex, $\chi^2(1) = 0.071$, BF_{01} independent multinomial $= 3.021$.

As in Experiment 1, no between-group differences were found regarding the QMI scores, $t(57.10) = 0.762$, $p = 0.762$, *Cohen's d* $= -0.079$, $BF_{01} = 3.665$, EPQ-N, $t(57.06) = -0.488$, $p = -0.126$, $BF_{01} = 3.447$, US- unpleasantness, $t(56.07) = 0.487$, $p = 0.628$, *Cohen's d* $= -0.127$, $BF_{01} = 3.802$, US-intensity, $t(52.66) = -0.246$, $p = 0.807$, *Cohen's d* $= -0.065$, $BF_{01} = 3.637$, or US-startlingness, $t(56.47) = 0.332$, $p = 0.741$, *Cohen's d* $= 0.086$, $BF_{01} = 3.613$. No between group differences were also detected for the STAI-S at the beginning, $t(57.99) = 0.60$, $p = 0.554$, *Cohen's d* $= 0.154$, $BF_{01} = 3.283$, or end of the experiment, $t(57.07) = -0.66$, $p = 0.512$, *Cohen's d* $= -0.171$, $BF_{01} = 3.172$, or STAI-T, $t(55.48) = 1.352$, $p = 0.182$, $BF_{01} = 1.775$. Also, no between-group differences were detected in terms of image vividness rating, $t(57.96) = 1.29$, $p = 0.204$, *Cohen's d* $= 0.332$, $BF_{01} = 1.909$. Finally, no between group differences were detected for the motivation to complete the task, $t(54.81) = 0.369$, $p = 0.713$, $p = 0.098$, $BF_{01} = 3.524$, or to fill in the questionnaires, $t(55.99) = 1.179$, $p = 0.243$, *Cohen's d* $= 0.309$, $BF_{01} = 2.109$. For detailed scores across groups, please see the Supplementary materials.

5.2. US-expectancies

The mean US-expectancies across all phases are shown in Fig. 3.

During the Pavlovian phase, participants reported different US-expectancies, CS x Trial, $F(5.99, 347.42) = 112.295$, $p < 0.001$, $\eta_p^2 = 0.659$, $BF_{10} = 10 \times 10^{1000}$, which was similar across groups, CS x Trial x Group, $F(5.99, 347.42) = 1.925$, $p = 0.076$, $\eta_p^2 = 0.032$, $BF_{01} = 18.221$. Post-hoc tests showed different US-expectancies between A and B, *pHolm* < 0.001, $BF_{10}U = 1.997 \times 10^{88}$, and A and C, *pHolm* < 0.001, $BF_{10}U = 8.652 \times 10^{84}$. No between-group differences were found on the first trial between A and B, *pHolm* $= 1$, A and C, *pHolm* $= 1$, and C and B, *pHolm* $= 1$.

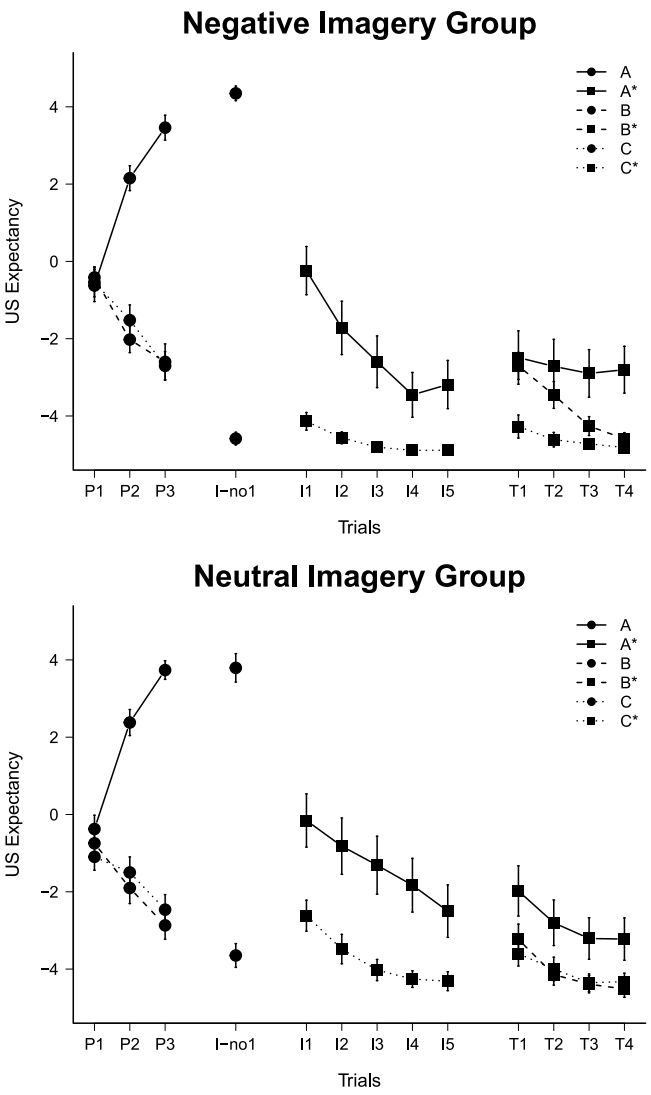

Fig. 3. Experiment 3: Mean US-expectancy ratings for all CSs across the whole experiment for the Negative Imagery Group (top panel) and the Neutral Imagery Group (bottom panel).

In the instrumental phase, participants also reported higher US-expectancies for A compared to C, CS x Trial, $F(3.09, 179.48) = 4.972$, $p = 0.002$, $\eta_p^2 = 0.079$, $BF_{01} = 1.335$. Again, this differentiation was similar across groups, CS x Trial x Group, $F(3.09, 179.48) = 2.528$, $p = 0.057$, $\eta_p^2 = 0.042$, $BF_{01} = 7.473$.

There were differences during the Test phase, CS $F(1.23, 71.16) = 14.853$, $p < 0.001$, $\eta_p^2 = 0.018$, $BF_{10} = 8791.582$, but not as a function of Trial, CS x Trial, $F(3.59, 208.08) = 1.77$, $p = 0.143$, $\eta_p^2 = 0.030$, $BF_{01} = 98.365$, or Group, CS x Group, $F(1.23, 71.16) = 1.09$, $p = 0.315$, $\eta_p^2 = 0.018$, $BF_{10} = 0.390$. Post-hoc analyses for the CS main effect showed significant differences between A and B, *pHolm* $= 0.003$, $BF_{10}U = 134608.547$, A and C, *pHolm* < 0.001, $BF_{10}U = 1.524 \times 10^{19}$, and B and C, *pHolm* $= 0.005$, $BF_{10}U = 725.819$.

Collectively, these results suggest that the negative imagery protocol did not result in different US-expectancies compared to the

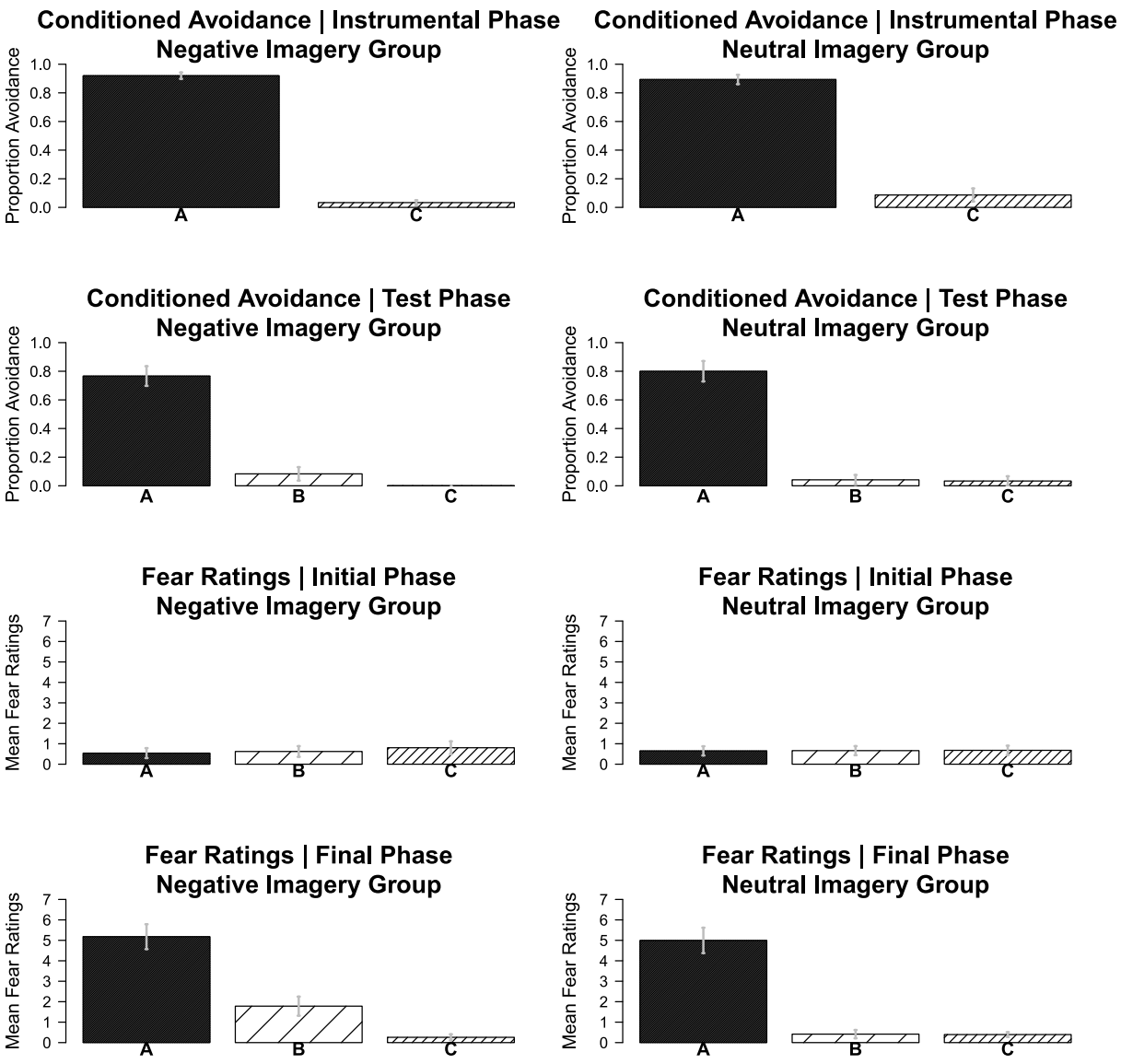

Fig. 4. Experiment 2: Mean proportion of avoidance responses for each CS and for each group during the instrumental (top panel) and test phase (second panel). Fear ratings for each CS and for each group (bottom two panels). *Initial* refers to the fear ratings before the conditioning phase and *Final* refers to the fear ratings after the test phase.

neutral imagery protocol.

5.3. Avoidance

Fig. 4 (top two rows) shows mean proportions of avoidance reactions for the instrumental and the test phase.

Results showed that during the instrumental phase, participants learned to press the space bar more often during the presentation of A compared to C, CS $F(1, 58) = 968.68$, $p < 0.001$, $\eta_p^2 = 0.944$, $BF_{10} = 6.760 \times 10^{53}$, in both groups, CS x Group, $F(1, 58) = 2.61$, $p = 0.111$, $\eta_p^2 = 0.043$, $BF_{01} = 1.201$.

Between CS differences were detected in the test phase, CS, $F(1.53, 88.72) = 142.188$, $p < 0.001$, $\eta_p^2 = 0.710$, $BF_{10} = 2.164 \times 10^{38}$, but this pattern was not different for groups, CS x Group $F(1.53, 88.72) = 0.058$, $p = 0.902$, $\eta_p^2 = 0.001$, $BF_{01} = 9.376$. Post-hoc analyses for the CS main effect showed significant differences between A and B, $pHolm < 0.001$, $BF_{10}U = 1.149 \times 10^{15}$, A and C, $pHolm < 0.001$, $BF_{10}U = 8.522 \times 10^{16}$, but no differences between B and C, $pHolm = 0.181$, $BF_{10}U = 2.816$. Taken together, there was no evidence that the imagery manipulation of Experiment 2 increased avoidance responses.

5.4. Fear ratings

Fig. 4 (bottom two rows) show the fear ratings for each group in the beginning and at the end of the experiment. Both groups evaluated the CSs differently, CS $F(1.42, 82.15) = 56.947$, $p < 0.001$, $\eta_p^2 = 0.495$, $BF_{10} = 5.026 \times 10^{13}$, and this effect differed as a function of time, CS x Trial $F(1.73, 100.27) = 90.244$, $p < 0.001$, $\eta_p^2 = 0.609$, $BF_{10} = 3.049 \times 10^{14}$, but not as a function of group, $F(1.42, 82.15) = 1.279$, $p = 0.275$, $\eta_p^2 = 0.022$, $BF_{01} = 5.089$, or trial and group, CS x Trial x Group $F(1.73, 100.27) = 2.383$, $p = 0.105$, $\eta_p^2 = 0.039$, $BF_{01} = 2.291$. Post-hoc comparisons of the CS x Trial interaction showed that no differences between stimuli at the beginning of the experiment, all $t < 1$, $p > 0.90$, but at the end, there were different ratings to A compared to C, $pHolm < 0.001$, A compared to B, $pHolm < 0.001$, but not to C compared to B, $t = -2.537$, $pHolm = 0.119$.

6. Discussion

We attempted to replicate the results of Experiment 1 by using a simpler procedure in which participants were asked to imagine only the US, and not the CS, *without any explicit mention of the CS-US relationship*. Results showed that the *Negative imagery* group, which was asked to imagine the US whenever B- was presented, and the *Neutral imagery* group showed similar levels of avoidance and CS fear ratings to this stimulus compared to the control stimulus (C-). The results were largely similar for US-expectancies, with higher ratings for the *Negative imagery* group compared to the *Neutral imagery* group. Collectively, we did not find evidence that imagery of a US in the presence of a safe CS is sufficient for the acquisition of avoidance and subjective measures of fear.

6.1. General discussion

We tested whether two imagery procedures could result in the induction of conditioned avoidance and subjective measures of fear (i.e., US-expectancies and fear ratings). Experiment 1 showed that participants who were instructed to imagine the association between a safe CS, a shock US, and their fear responses, showed more avoidance responses and subjective fear for that CS, compared to individuals who were instructed to imagine associations of the same CS with a neutral tone. Experiment 2 showed that just imagining a shock US, while seeing a safe CS, did not lead to conditioned avoidance or higher fear for that. Collectively, the results indicate that mental imagery could lead to conditioned avoidance and subjective fear but only when the CS, US, and their association are imagined.

Our previous work has shown that *avoidance reflex-like tendencies* can be acquired via mere learning of CS-US associations. Specifically, the research by Krypotos, Effting, Arnaudova, Kindt, and Beckers (2014) showed that after undergoing a differential fear conditioning procedure, participants were faster to avoid the CS + and approach the CS- than the reverse. Experiment 1 extends these findings by showing that mere imagination of a CS-US association can also result in the acquisition of *overt avoidance*.

The finding that conditioned avoidance can be acquired via mental imagery could explain past reports of people with phobias who report no history of conditioning via direct experience (Rachman & Silva, 1978). The common explanation for these findings is that fear can also be acquired via instructions or observation (Mineka & Zinbarg, 2006). Recent experiments indeed show that avoidance can be acquired via these pathways (e.g., Cameron, Schlund, & Dymond, 2015; Dymond, Schlund, Roche, De Houwer, & Freegard, 2012. Our findings extend prior results and theories in two important ways. First, they suggest that psychopathology and avoidance could be acquired without social interactions or direct experience, although experience with an aversive/phobic event (here the US) seems to be necessary. Second, this procedure may not even need to include instructions about the avoidance response per se (i.e., that it may cancel the US presentation) as in previous studies (Dymond et al., 2012). It may be sufficient that the imagery procedure only refers to CS-US associations without any reference to how the US may be avoided.

In their review of imagery in conditioning research, Dadds et al. (1997) separated different elements of conditioning procedures that could be parts of imagery protocols, such as CS-US pairings or only the US when the CS is presented. Along that line, we tested in Experiment 2 whether conditioned avoidance and subjective fear could also be acquired, as in Experiment 1, when participants were only asked to imagine the US whenever a CS- was presented, and without being told the potential contingencies between the CS and US (see also Jones & Davey, 1990). We did not find any evidence that this procedure leads to the acquisition of avoidance or subjective fear.[1] Combined with the results of Experiment 1, these findings suggest that the *acquisition of overt avoidance* via mental imagery is possible when participants imagine the CS, the US (including their responses to it), and their association.

There are different explanations as to why Experiment 2 did not extend the results of Experiment 1 to procedures where just US rehearsal, while seeing the CS, is sufficient for the establishment of conditioned responses. First, repeatedly imagining the US in Experiment 2 could have extinguished the conditioned responses towards the B- throughout the imagery procedure. Second, combined with the findings by Jones and Davey (1990), it could be argued that although imagining the US in the presence of a CS can result in the *maintenance* of CRs, it is not sufficient for the *acquisition* of CRs or avoidance. Third, it may be easier to install fear and avoidance by mental imagery of CS-US contingencies than by merely imaging the US. Indeed, previous research has found that mental imagery of the US can lead to heightened fear responses, but only for more anxious participants (Davey & Matchett, 1994). In our recent review on mental imagery and conditioning, we also found that different imagery procedures lead to different conditioning results (see Table 2 of Mertens et al., 2020). Subsequent research in which these two types of imagery are directly compared could shed more light on this issue. It should also be noted that in both experiments, participants experienced the electric stimulation but not the neutral tone. This could have resulted in more vivid imagery in the Negative imagery group than the Neutral imagery group, but it does not explain the null-findings of Experiment 2.

One alternative explanation for our findings could be fear learning through verbal instructions (Dymond et al., 2012; Mertens et al., 2018). However, such an explanation cannot easily accommodate the results of Experiment 1, in which the imagery scenario referred to the CS-US contingencies only with no reference to the avoidance response, or the null results of Experiment 2. Furthermore, rather than an alternative learning pathway, mental imagery could be the mediating mechanism between instructions and their effects on avoidance and fear responses (). Hence, these two explanations (i.e., instructions and mental imagery) are not necessarily mutually exclusive. Future research could clarify the specific effects of instructions and mental imagery by comparing the acquisition of avoidance responses in participants who are merely instructed about the CS-US relationship compared to participants who are asked to vividly imagine the CS-US relationship (i.e., see Experiment 1).

The results provide pointers towards the further investigation of the role of mental imagery on conditioned avoidance. For example, future research could test whether an imagery protocol could result in the reduction of conditioned avoidance responses if individuals are asked to imagine that a CS + is no longer followed by a US. Also, similar to the research by Dymond et al. (2012), a comparison of different pathways of avoidance acquisition (i.e., direct experience, instructions, observational learning, and mental imagery) could be useful for investigating potential differences in the rate of avoidance, and maybe subjective fear (Raes, De Houwer, De Schryver, Brass, & Kalisch, 2014).

In summary, this research shows that conditioned avoidance and subjective fear can be induced when participants are asked to imagine a CS being followed by a US, but not when they are asked to imagine just the US whenever the CS is presented. Our results provide a first indication that mental imagery can result in conditioned avoidance, but also call for further investigation in this area.

CRediT authorship contribution statement

Angelos-Militaris Krypotos: Conceptualization, Methodology,

[1] Notably, no subjective measures of fear were collected in Jones and Davey (1990), but only physiology measures. Past work has shown that subjective and physiological measures of fear not always covary (Mauss & Robinson, 2009).

Writing - review & editing, Data curation, Formal analysis, Software, Writing - original draft. **Gaëtan Mertens:** Conceptualization, Methodology, Writing - review & editing. **Arne Leer:** Conceptualization, Methodology, Writing - review & editing. **Iris M. Engelhard:** Conceptualization, Methodology, Writing - review & editing.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2020.103652.

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