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Dual processes in fear and anxiety: no effects of cognitive load on the predictive value of implicit measures

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ABSTRACT

Dual process models posit that combinations of impulsive and reflective processes drive behaviour, and that the capacity to engage in effortful cognitive processing moderates the relation between measures of impulsive or reflective processes and actual behaviour. When cognitive resources are low, impulsive processes are more likely to drive behaviour, while when cognitive resources are high, reflective processes will drive behaviour. In our current study, we directly addressed this hypothesis by comparing the capacity of implicit and explicit measures to predict fear and anxiety, either with or without additional cognitive load. In Experiment 1 ($N = 83$), only explicit measures of spider fear were predictive of spider avoidance, and manipulating cognitive load did not affect these relations. Experiment 2 ($N = 70$) confirmed these findings, as the capacity of explicit and implicit measures to predict self-reported and physiological responses to a social stressor was not moderated by cognitive load. In two experiments, we thus found no empirical support for the central dual process model assumption that cognitive control moderates the predictive value of implicit and explicit measures. While implicit measures and dual process accounts may still be valuable, we show that results in this field are not necessarily replicable and inconsistent.

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Both normal and pathological behaviours have been explained in the context of dual process models (e.g. Hofmann et al., 2009; Ouimet et al., 2009; Strack & Deutsch, 2004). The central assumption of these models is that behaviour is driven by two distinct processes. *Impulsive* processes are more automatic and their strength is derived from so-called implicit measures, typically using reaction times (RTs) to measure affective reactions, approach/avoidance-behaviour, or attentional bias (AB, i.e. the preferential allocation of attention to or difficulty to disengage attention from certain categories of stimuli). *Reflective* processes are more conscious, deliberate, strategic, and require cognitive resources. Reflective processes

are typically measured through explicit measures, often using self-report questionnaires to measure people's more conscious attitudes, behaviours, or emotional responses.

Although a strict separation between fully impulsive and fully reflective processes has been criticised (e.g. Melnikoff & Bargh, 2018), relatively impulsive and relatively reflective processes are assumed to operate in parallel. Whether either impulsive or reflective processes eventually drive behaviour depends on situational and individual factors. The ability or capacity to engage in effortful cognitive processing is arguably the most important of these factors. When cognitive resources are low, for example in

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stressful situations, or if individuals have low cognitive control or low working memory capacity (WMC), behaviour is more likely driven by impulsive processes. Inversely, when cognitive resources are high or individuals have high WMC, behaviour more likely stems from reflective processes. Implicit measures should thus predict behaviour when people have limited cognitive resources, while explicit measures should predict behaviour when people have ample cognitive resources (Frieze, Hofmann, & Schmitt, 2008; Hofmann et al., 2009).

Initial studies in the context of food consumption, alcohol use, and smoking supported the moderating role of cognitive control in predicting behaviour (e.g. Frieze, Hofmann, & Wänke, 2008; Spruyt et al., 2015). For instance, Frieze et al. used different versions of the Implicit Association Test (IAT: Greenwald et al., 1998) to measure automatically activated associations between different kinds of foods and drinks and the concepts pleasant and unpleasant. In a first experiment, implicit but not explicit liking of chocolate was predictive of the number of chocolates that participants took in a free choice task, but only in a group of participants who performed a secondary cognitive load task. Inversely, in a group without additional cognitive load, the explicit but not the implicit measure of chocolate liking predicted the number of chocolates taken. Similar results were found for the consumption of potato crisps (Experiment 2) and beer (Experiment 3), leading the authors to conclude that cognitive control moderates the capacity of implicit and explicit measures to predict behaviour.

In research on fear and anxiety, several studies have shown that implicit measures can predict fear-related behaviour over and above explicit measures, and that only implicit measures are predictive of outcome behaviours that are less easily controlled, like physiological responses (e.g. de Hullu et al., 2011; Egloff & Schmukle, 2002; Huijding & de Jong, 2006; Van Bockstaele et al., 2011). For instance, Van Bockstaele et al. (2011) found that measures of AB for spiders, difficulty to disengage attention from spiders, and negative implicit spider associations were all predictive of changes in heart rate in response to a spider encounter, while self-reported spider fear was not. However, the potentially crucial moderating role of cognitive control in the relation between implicit measures and behaviour has received only limited attention.

Gorlin and Teachman (2015) found that individual differences in inhibitory control moderated the

relation between a measure of relatively automatic attention for social threat words and measures of social anxiety. While more attention for social threat words was related to more anxiety in participants scoring low in inhibitory control, less attention for social threat words was related to more anxiety in participants with high levels of inhibitory control. However, the study did not assess whether the prediction of anxiety based on explicit measures of social anxiety was also moderated by measures of cognitive control. In another study, Effting et al. (2016) addressed the moderating role of WMC in the prediction of spider avoidance. They measured relatively automatic approach/avoidance tendencies using an approach-avoidance task as well as implicit negative spider associations using an IAT. Although none of their measures was predictive of the speed with which participants approached a spider, they found that WMC moderated the relation between implicitly measured spider attitudes and approach distance. For participants with lower WMC, stronger negative implicit spider attitudes were associated with less approach, while for participants with higher WMC, the strength of implicit spider attitudes was not predictive of approach distance. Contrary to the theory however, the predictive value of an explicit measure of spider fear was not moderated by WMC: While dual process theories assume that explicit measures are more predictive of behaviour when people have ample cognitive resources, Effting et al. found that explicit spider fear was predictive of approach distances in participants with both high and low WMC.

Although there is thus some evidence supporting the moderating role of cognitive control in the capacity of implicit and explicit measures to predict fear- and anxiety-related outcomes, this evidence is equivocal. The fact that both Gorlin and Teachman (2015) and Effting et al. (2016) measured cognitive control as an individual, dispositional factor could partly account for these inconsistencies: To unambiguously demonstrate the possible causal impact of cognitive control on the predictive value of implicit and explicit measures, levels of cognitive control should be experimentally manipulated, and this manipulation should affect the predictive value the measures. In our present study, we directly addressed the moderating role of cognitive control by experimentally inducing cognitive load in one group of participants, while no cognitive load was induced in a control group. In Experiment 1, we used implicit measures of AB for spiders, difficulty to disengage

attention from spiders, and automatically activated spider attitudes, and an explicit spider fear questionnaire to predict real-life behavioural avoidance of a spider. Following dual process models, we expected the implicit measures to be predictive of avoidance in participants who were exposed to the high cognitive load induction but not so (or to a lesser extent) in participants in a low-load control group. Inversely, we expected the explicit measure to be more predictive of avoidance in participants in the control group, and less so in the load group.

Experiment 1

Method

Participants

Eighty-four participants were recruited from the student participant pool of the University of Amsterdam. One participant stopped the experiment after completing only the spider fear questionnaire; their data were removed, resulting in a final sample of 83 participants (24 men, $M_{\text{age}} = 22.78$, $SD = 5.70$). A power analysis using G*Power (Faul et al., 2007) showed that for a sample of 83 participants, a model with nine predictors and conventional values of .80 for power and .05 for statistical significance, we had adequate statistical power to detect effect sizes of $f^2 = 0.21$ and larger, reflecting medium to large effects.¹

Procedure

In this section, we describe the general procedure and timeline; details of the tasks are provided below. Before the start of the experiment, participants were informed about the general nature of the stimuli and tasks and they were informed that they could end their participation at any moment. They then provided written informed consent, but they were not yet informed of the Behavioural Approach Task (BAT). Next, they completed the spider fear questionnaire, the IAT, the AB assessment task, and the attentional disengagement task, and a neutral flanker task, in this order, in a soundproof cubicle. Upon completing these tasks, they were informed of the BAT and they were reminded that they were not obliged to continue their participation. Participants who agreed to start the BAT were taken to a separate lab where they performed the test. Throughout the entire experiment, the experimenter was blind to the cognitive load manipulation. After the experiment, participants

were debriefed and reimbursed with either course credits or money. The procedure lasted for about 30 min and it was approved by the ethical committee of the University of Amsterdam (ref. number 2014-DP-3678).

Questionnaires

Explicit spider fear was measured using the Dutch translation of the Fear of Spiders Questionnaire (FSQ; Muris & Merckelbach, 1996). This questionnaire consists of 18 items scored on 8-point Likert scales ranging from 0 to 7, resulting in scores between 0 and 126.

Stimulus materials

For the dot probe task, the disengagement task, and the IAT, we used a total of 24 pictures of spiders (Van Bockstaele et al., 2011) and 24 pictures of mushrooms (matching the mostly “earthy” colours in the spider pictures), divided in sets of eight pictures for each task. For practice trials in the dot probe task and the disengagement task, we used a set of eight flower pictures. All pictures measured 250×210 pixels and were selected from the internet.

Implicit Association Test

The IAT was modelled after Greenwald et al. (2003) and consisted of seven blocks. During each block of the IAT, the relevant response labels (“POSITIVE”, “NEGATIVE”, “SPIDER”, “MUSHROOM”) remained on the top left and right on the screen, correctly reminding participants which button (left or right, i.e. A- or L-key of the keyboard) to use for each category. Each block started with the presentation of the relevant labels for 3s. All stimuli were presented in the centre of the screen and remained on the screen until a response was registered. Participants categorised each stimulus as quickly and as accurately as possible. The intertrial interval was 350ms.

In the first block, the attribute categories were practiced in 32 trials. Attribute stimuli were either negative words (“war”, “pain”, “misfortune”, “death”, “hate”, “disease”, “aversion”, “funeral”) or positive words (“holiday”, “summer”, “gift”, “present”, “warmth”, “party”, “pleasure”, “cheerful”), and every word was presented twice. In the second block, the target categories were practiced, using eight spider pictures and eight mushroom pictures. Each picture was presented twice, resulting in 32 trials. Spiders were categorised using the same button as negative words in the first block. The third block

was the compatible practice block, consisting of 32 trials in which attribute and target categories were presented intermixed, with spiders and negative words sharing the same response button. Each word and each picture was presented once. The fourth block was the compatible test block and was identical to the third block but consisted of 64 trials (each picture and each word presented twice). In the fifth block, the target category response buttons were reversed and consisted of 32 trials, with all pictures presented twice. In the sixth block, the incompatible categorisation (spider-positive versus mushroom-negative) was practiced in 32 trials (each word and each picture presented once). The seventh block was the incompatible test block, consisting of 64 trials and each word and each picture was presented twice.

Attentional bias assessment task: dot probe task

AB for spiders was assessed using a dot probe task. Trials started with a central white fixation cross and two grey rectangles (250×210 pixels, one above and one below the fixation cross) on a black background. After 500ms, the grey rectangles were replaced by two cue pictures. After another 500ms, the cue pictures were masked for 20ms by the grey rectangles and the target appeared in the centre of the grey rectangles. Targets consisted of either the letter E or the letter F, and participants responded as fast and as accurately as possible to the target identity by pressing the A- or L-key of a keyboard. Targets remained on the screen until a response was registered, and the next trial started 500ms after response registration.

The task consisted of two blocks. A practice block, consisting of 12 trials, used pictures of flowers as cues, and a 500ms error message was presented after incorrect responses. The test block consisted of 128 trials in which a randomly selected spider picture was paired with a randomly selected mushroom picture. On half of the trials, the target appeared on the location of the spider picture (*congruent* trials), and on the other half of the trials, the target appeared on the location of the mushroom picture (*incongruent* trials). AB in this task is operationalised as the difference in RTs on congruent versus incongruent trials. All pictures and targets were presented equally often in either position, targets were equally often E or F, and pictures were not predictive of either target position or target identity.

Attentional disengagement task

Each trial in the disengagement task started with a white fixation cross on a black background. After 500ms, a single picture replaced the fixation cross for 500ms. After the picture was erased, a target stimulus (E or F) appeared 6cm above or below the centre of the screen. Participants responded as fast and accurately as possible to the identity of the target, using the same response buttons as in the dot probe task.

The task consisted of a practice block and a test block. The practice block consisted of 12 trials with error feedback and flower pictures. The test block consisted of 128 trials, half of which contained a spider picture and the other half a mushroom picture. Target identities and positions were balanced, and pictures were not predictive of either the location or the identity of the target.

Flanker task

In line with Frieese, Hofmann, and Wänke (2008), we manipulated cognitive load by asking participants to memorise either an easy or a difficult 8-digit numerical code. To check whether this manipulation indeed induced cognitive load, participants performed a flanker task (Eriksen & Schultz, 1979), in which four different letter strings were presented (EEEE, FFFF, EEFEE, or FFEFF), preceded by a 500ms fixation cross, and participants identified the third letter as fast as possible by pressing one of two response buttons. The main task was preceded by a short practice block, consisting of 12 trials with each letter string presented three times. Next, participants were instructed to memorise a numerical code (high load: 49708316; low load: 22222222) which they would have to reproduce after the test block. The code was presented for 20 s, after which a 60-trial test block started, in which each letter string was presented 15 times. After the last trial, participants reproduced the code.

Behavioural Approach Test

Before starting the BAT, participants were informed that they would accompany the experimenter to a different room in which they would be asked to bring their hand as closely as possible to a real, living tarantula. This spider's bite was told to be venomous but not lethal, similar to a wasp sting. In reality, we used only the exoskeleton of a tarantula, the abdomen of which was covered by a broken

flowerpot. Participants were told that it was up to them to decide how closely they wanted to approach the spider, and that they could end their participation at any time. Finally, they were told the experimenter was trained to deal with spiders, and that they would remove the spider as soon as participants indicated that they wanted to stop the test. Participants who agreed to do the test were taken to a separate lab, where a covered box containing the spider was placed on a table, at the end of a 2m long measuring tape. Participants memorised a new 8-digit numerical code (high load: 16925708; low load: 33333333), which was again presented for 20 s and which they would later need to reproduce. Next, they put their dominant hand at the 2m mark of the measuring tape, the box covering the spider was lifted, and they moved their hand forward over the measuring tape until they decided they wanted to stop. We registered the minimal distance between participants' hands and the spider, as well as the time it took participants to reach this distance. Finally, participants reproduced the numerical code.

Results

Scoring and outlier analysis

For the IAT, we calculated the D600 score as described by Greenwald et al. (2003), so that larger scores reflect more negative implicit associations with spiders compared to mushrooms. For the dot probe task, data of two participants whose percentage of correct responses deviated more than 3SDs from the group mean ($M = 92.78\%$ correct, $SD = 4.48$, cut-off = 79.34, participants' scores = 76.56 and 78.91) were removed. Next, we removed trials with errors (6.85%) and trials with outlying RTs (4.64%) using the median absolute deviation procedure described by Leys et al. (2013), with the moderately conservative threshold of 2.5. For the remaining trials, we calculated AB-scores by subtracting mean RTs on congruent trials from mean RTs on incongruent trials. Larger AB-scores thus indicate a stronger AB for spiders. In the disengagement task, we used the same outlier criteria, resulting in the removal of two participants who made too many errors (group $M = 93.67\%$ correct, $SD = 6.64$, cut-off = 73.75, participants' scores = 52.34 and 68.75), trials with errors (5.53%), and outlying RTs (4.91%). Disengagement scores were calculated by subtracting mean RTs for mushroom trials from mean RTs for spider trials. For the flanker task, we removed one participant who made

too many errors (group $M = 92.53\%$ correct, $SD = 6.99$, cut-off = 71.56, participant's score = 55.00% correct), errors (7.01%), and outlying RTs (6.71%). For both RTs and error rates, we calculated congruency effect scores as the difference between congruent and incongruent trials. Finally, for the BAT, the time registration for one participant was missing due to an experimenter error. In addition, two participants indicated that they did not want to start the BAT, so their scores were set to missing for all analyses involving the BAT.

Statistical approach

Our main hypothesis that the predictive value of implicit and explicit measures depends on the availability of cognitive resources was tested in separate regression models predicting approach distance and approach speed. For both models, we included the explicit (FSQ) and the three implicit measures (IAT, AB, disengagement) of spider fear (all as continuous variables), as well as the dummy-coded cognitive load group, and the interactions between load group and the implicit and explicit measures of spider fear. All continuous variables were z-standardised.

Because the outcomes of regression models can be influenced by outliers, we identified possible outlying or influential cases following the recommendations of Aguinis et al. (2013) in an analysis including all participants. We flagged potential outliers (i.e. cases with either leverage, Mahalanobis distance, studentized deleted residuals, Cook's distance, or standardised differences in fit exceeding design-specific cut-offs), and then tested each regression model again after removing these outliers. We present the results of the sample after outlier exclusion below. The models including all participants yielded similar patterns of results, which are provided in the online supplement. Because we thus ran each model twice, we adjusted our alpha levels for model significance to .025, and because each model included 9 predictors, individual predictor significance levels were adjusted .0055 (i.e. .05/9).

Group characteristics, basic results, and manipulation check

Descriptive statistics for all measures are presented in Table 1. To assess participants' attentional preference for spiders over mushrooms and the extent to which they associated negative words more readily with spiders than with mushrooms, we tested whether the scores on the implicit measures differed from zero. One-sample *t*-tests showed that scores on the dot

Table 1. Descriptive statistics of all measures in Experiment 1.

	Total Sample ^a			Reliability ^b	Low Anxious		High Anxious		<i>t</i> diff. ^c	<i>p</i> diff.
	<i>N</i>	<i>M</i>	<i>SD</i>		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
FSQ	83	28.87	25.65	.96	8.00	7.15	49.90	19.90	12.69	.00
AB (ms)	81	-8.43	19.34	.10	-7.56	17.28	-9.64	21.50	0.48	.63
Disengagement (ms)	81	-0.55	19.32	.16	3.60	19.32	-2.26	19.30	1.36	.18
IAT D600	83	0.35	0.31	.82	0.35	0.32	0.35	0.32	0.00	.99
BAT Distance (cm) ^d	81	32.62	42.48	-	10.65	12.11	54.83	50.52	5.39	.00
BAT Time (sec)	80	25.86	11.98	-	23.56	10.92	27.80	12.72	1.59	.12
BAT Speed (cm/sec)	80	8.00	4.67	-	10.06	5.05	6.08	3.33	4.14	.00

Notes: FSQ = Fear of Spiders Questionnaire; AB = Attentional Bias; IAT = Implicit Association Test; BAT = Behavioural Approach Task.

a. For correlations between measures, see Table S1 in the online supplement. b. For the FSQ, the reliability estimate is Cronbach's alpha. For the RT tasks, the reliability estimate is the Spearman-Brown corrected split half reliability. c. One participant was not included in the high versus low comparisons, because they scored on the median and could not unambiguously be assigned to a group. d. Distance reflects the minimum distance between participants' hand and the spider (i.e. smaller values mean that participants finished the BAT with their hand closer to the spider).

probe task and the IAT differed significantly from zero, $t(80) = 3.92$, $p < .001$, and $t(82) = 10.07$, $p < .001$, respectively, indicating that our sample overall showed attentional avoidance of spiders (or an AB for mushrooms) and had more negative implicit associations with spiders compared to mushrooms. The disengagement score did not differ significantly from zero, $t < 1$, indicating that participants had no more difficulty disengaging their attention from spiders than from mushrooms. Reliability estimates of the AB and disengagement scores were very poor, while the IAT and the FSQ showed good reliability. Comparing high versus low spider fearful participants based on median-split FSQ scores yielded significant group differences on the BAT approach distance and speed, with low fearful participants approaching the spider closer and faster than high fearful participants. There were no significant differences between high and low anxious participants on the approach time or on any of the implicit measures.

To address whether the easy and difficult numerical codes imposed different cognitive loads on participants, we compared the high and low load groups' performance on the flanker task. Participants in the high load group were overall significantly slower than participants in the low load group, $t(78) = 3.34$, $p = .001$, but they did not make more errors, $t < 1$, nor did they differ significantly on either the RT or error congruency effects, both t s < 1.50 , both p s $> .13$. For the flanker code, all participants in the low load group correctly reproduced the code, while participants in the high load group on average correctly reproduced 7.45 digits ($SD = 1.18$). For the BAT, all participants in the low load group again correctly reproduced the code, while participants in the high load group on average correctly reproduced 7.10 digits ($SD = 1.66$).

Predicting avoidance behaviour

In the regression predicting approach distance, after 11 potential outliers were excluded, the full model was significant, $F(9, 57) = 8.09$, $p < .001$, $R^2 = .56$, $f^2 = 1.27$ (Table 2). However, only the FSQ was a significant predictor of approach behaviour, with higher explicit spider fear predicting less approach. None of the implicit measures nor any of the interactions between measures of spider fear and load group were significant. The regression predicting approach speed, for which 5 potential outliers were excluded, yielded similar results: The overall model was significant, $F(9, 62) = 4.90$, $p < .001$, $R^2 = .42$, $f^2 = 0.72$, but only the FSQ significantly predicted approach speed, with higher explicit spider fear predicting slower approach (Table 2).

Discussion

Contrary to our expectations, implicit measures were not predictive of avoidance behaviour under high cognitive load. A straightforward explanation for this null finding is that the cognitive load hypothesis does not hold in the context of fear and anxiety. However, at least three methodological limitations can also account for our findings. First, the AB and disengagement scores were unreliable, making them problematic as predictors of individual differences (De Schryver et al., 2016). Second, memorising an eight-digit number may not have been a strong enough manipulation of cognitive load. Third, we measured only overt avoidance behaviour, and some studies have shown that implicit measures of fear are related to uncontrollable (physiological) but not controllable responses (e.g. Huijding & de Jong, 2006; Van Bockstaele et al., 2011). We therefore ran

Table 2. Linear regression analyses predicting spider approach distance and speed.

Dependent variable	Predictor	<i>B</i>	<i>SE</i>	β	<i>t</i>	<i>p</i>
Approach distance	constant	-0.16	0.07		2.28	.03
	FSQ	0.40	0.07	0.74	5.71	.00
	AB	-0.01	0.06	-0.02	0.18	.86
	Disengagement	-0.03	0.10	-0.06	0.30	.77
	IAT	0.09	0.07	0.17	1.26	.21
	Load	-0.10	0.09	-0.11	1.17	.25
	Load X FSQ	0.00	0.10	0.01	0.04	.97
	Load X AB	0.07	0.09	0.10	0.74	.46
	Load X Disengagement	0.01	0.11	0.01	0.06	.95
	Load X IAT	-0.10	0.10	-0.14	1.05	.30
Approach speed	constant	-0.16	0.12		1.39	.17
	FSQ	-0.47	0.10	-0.60	4.72	.00
	AB	-0.07	0.11	-0.08	0.59	.55
	Disengagement	-0.26	0.18	-0.29	1.43	.16
	IAT	-0.20	0.12	-0.24	1.68	.10
	Load	0.08	0.16	0.05	0.49	.62
	Load X FSQ	0.10	0.16	0.08	0.65	.52
	Load X AB	0.08	0.17	0.07	0.49	.63
	Load X Disengagement	0.39	0.21	0.36	1.82	.07
	Load X IAT	0.29	0.17	0.24	1.73	.09

Notes: FSQ = Fear of Spiders Questionnaire; AB = Attentional Bias; IAT = Implicit Association Test.

a second experiment, in which we measured AB using the more reliable visual search task (Van Bockstaele et al., 2020), we used the Random Interval Repetition (RIR: Vandierendonck et al., 1998) task to impose cognitive load, and next to self-reported negative mood, we added measures of heart rate and heart rate variability (HRV) as less controllable outcomes. We also switched from the spider fear domain to the social anxiety domain. Following dual process models, we expected that higher implicit social anxiety would be predictive of stronger increases in self-reported negative mood as well as increased heart rate and decreased HRV (Kreibig, 2010) following a social stressor in the cognitive load group but not so (or to a lesser extent) in the control group. Inversely, we expected that high scores on the explicit social anxiety measure would be associated with increases in self-reported negative mood, increased heart rate, and decreased HRV in response to a social stressor in the control group, and less so in the cognitive load group.

Experiment 2

Method

Participants

Seventy participants (17 men, $M_{\text{age}} = 26.04$, $SD = 9.95$) were recruited from the student participant pool of the University of Amsterdam. For a sample of 70 participants, a model with seven predictors and conventional values of .80 for power and .05 for statistical

significance, effect sizes of $f^2 = 0.23$ or larger were required.³

Procedure

Participants provided written informed consent after being informed about the nature of the stimuli and the computer tasks. They were not informed of the social stress task, but they were told that they could end their participation at any time. They completed the social anxiety questionnaire, the IAT, the visual search task, and the social stress task (with or without cognitive load manipulation) as described below, in this fixed order. After the experiment, participants were debriefed and rewarded with either course credits or money. The entire procedure lasted for about 30 min and was approved by the ethical committee of the University of Amsterdam (ref. number 2015-DP-4691).

Questionnaires

Explicit social anxiety was measured using the Dutch translation of the short Fear of Negative Evaluations Scale (FNES: Bögels, 2004). This questionnaire consists of 12 statements, each scored on a 5-point Likert scale.

Stimulus materials

For the visual search task, we used colour pictures of the angry and happy facial expressions of 48 actors (24 men and 24 women) from the Karolinska Directed Emotional Faces database (Lundqvist et al., 1998).

Pictures of an additional eight actors (4 men and 4 women) were used in practice blocks. Pictures were 5.6cm wide by 7.6cm high.

Implicit Association Test

We used an anxiety-identity IAT based on the one developed by Egloff and Schmukle (2002). Participants categorised centrally presented words belonging to four different categories as quickly as possible using two response buttons. The categories were ANXIOUS (“afraid”, “nervous”, “ashamed”, “criticized”, “insecure”), CALM (“calm”, “relaxed”, “accepted”, “carefree”, “secure”), SELF (“I”, “me”, “my”, “myself”, “own”), and NOT SELF (“themselves”, “they”, “their”, “others”, “you”). All words were presented in black on a white background with a 350ms inter-trial interval. A red “X” was shown for 400ms on incorrect responses. Implicit anxiety is inferred from the difference in RTs between blocks where ANXIOUS and SELF share one response button and CALM and NOT SELF share the other button versus blocks where CALM and SELF share one response button and ANXIOUS and NOT SELF share the other button.

The task consisted of seven blocks, and the relevant category labels were always visible in the top left and top right corners of the screen. In the first block, words belonging to the SELF and NOT SELF categories were presented twice, for a total of 20 trials. In the second block, words belonging to the ANXIOUS and CALM categories were also presented twice, again resulting in 20 trials. In the third block, participants practiced the combinations of SELF + CALM and NOT SELF + ANXIOUS, with each word presented once. The fourth block was identical to the third, but each word was presented three times, for a total of 60 trials. In the fifth block, the response buttons for ANXIOUS and CALM were reversed, with each word presented twice. In the sixth block, participants practiced the reversed combinations (SELF + ANXIOUS and NOT SELF + CALM) in 20 trials, with each word presented once. Finally, the seventh block was identical to the sixth block, but it consisted of 60 trials with each word presented three times.

Attentional bias assessment task: visual search

The visual search task was similar to one used by Van Bockstaele et al. (2017). Participants were required to find a target face that was presented amidst distractor faces. A central white fixation cross was presented for 500ms on a black background, after which eight unique faces were presented in a 3 × 3 grid

(17.3cm × 23.1cm) with the middle position containing the fixation cross. All faces were presented equally often, and target faces appeared equally often in any of the eight possible locations. The task consisted of a “find angry” block, in which participants clicked as fast as possible on an angry target while ignoring seven happy distractors, and a “find happy” block, in which participants clicked as fast as possible on a happy target while ignoring seven angry distractors. Both blocks consisted of 48 trials and were presented in a fixed order with the find angry block first. The intertrial-interval was 500ms. No error feedback was given. Each test block was preceded by a corresponding practice block consisting of eight trials with new faces and error feedback.

Social stress task and cognitive load manipulation

Prior to starting the social stress task, the experimenter entered to lab to attach the heart rate electrodes. ECG was measured using a custom-made portable amplifier with a 1GΩ input resistance and a bandwidth of 0.1Hz (6dB/oct) to 250Hz (24 dB/oct) containing a National Instruments NI-USB6210 A/D converter to digitise the analogue data at a rate of 1000 S/s. We used disposable pre-gelled Ag/AgCl 3M Red Dot electrodes placed in LEAD-II configuration.

The social stress task consisted of three phases: A 3-minute baseline phase, a 2-minute stress phase, and a 2-minute recovery phase. In the baseline, participants were asked to remain seated while avoiding movements. After this phase, participants rated on three separate 7-point Likert scales how anxious, stressed, and insecure they felt (1: “not at all”, 3: “a little”, 5: “fairly”, 7: “very much”). In the stress phase, a short text was shown on the screen, explaining to participants that they would be asked to give a non-stop 7-minute presentation in front of the experimenter and a judge about what makes them a good friend, and that they had two minutes to mentally prepare for this presentation. After two minutes, they again rated how anxious, stressed, and insecure they felt. Finally, in the recovery phase, participants were shown a brief text explaining that, based on their participant number, they were exempt from giving the presentation and that the experiment would end two minutes later. Again, they were asked to remain seated and avoid movements, and after two minutes, they rated their anxiety, stress, and insecurity.

During the three phases of the social stress task, we imposed a cognitive load on half of the participants

by having them continuously perform the RIR-task (Vandierendonck et al., 1998). Participants were asked to respond as fast as possible to a short tone that was presented at intervals varying randomly between 900, 1500, and 2100ms by clicking on the left mouse button. If participants did not respond within 2900ms, an error message reminding them to respond to the tone was presented for 500ms. Because the duration of the baseline, stress, and recovery phases was fixed, the amount of trials that participants completed in the RIR-task varied depending on participants' RTs and the random selection of the time-intervals between tones. On average, participants completed 97 RIR-task trials ($SD = 7$) in the baseline phase, and 62 ($SD = 6$) and 67 ($SD = 5$) trials in the stress and recovery phases, respectively. Participants in the no-load group did not perform a secondary task.

Results

Scoring and outlier analysis

For the IAT, we calculated D600 scores as described for Experiment 1, with positive scores reflecting stronger associations between oneself and anxiety and negative scores reflecting stronger associations between oneself and calmness. For the visual search task, we excluded the data of one participant who made too many errors (group $M = 98.72\%$ correct, $SD = 1.70$, cut-off = 93.62, participant's score = 89.58). Next, we removed errors (1.15%) and trials with outlying RTs (4.47%) using the median absolute deviation procedure. Finally, we calculated AB-scores by subtracting mean RTs on the find angry block from mean RTs on the find happy block. Larger scores thus indicate a stronger AB for angry faces.

For each phase of the social stress task, we averaged the scores of the three Likert items into a single negative mood score (Cronbach's alphas for each phase $> .76$). Two participants did not perform the RIR-task in the baseline phase (i.e. they did not respond to the tones). These participants were excluded from all analyses involving load group as they did not undergo the full load manipulation. Participants on average made 5.24% ($SD = 4.68$) errors (i.e. no response within 2900ms) on the RIR-task and had a mean RT of 384ms ($SD = 95$).

For the heart rate data, we used Vsrrp98 (2011) to detect R-tops from the ECG recording and to calculate heart rate and HRV (operationalised as the root mean square of successive differences in inter-beat-

intervals) allowing a maximum difference of $\pm 33\%$ in successive IBI length for HRV. ECGs were visually inspected and areas with poor signal and/or artefacts were manually removed or corrected if possible. For two participants, the signal was lost at the end of the stress induction phase. Finally, for one participant, all heart rate data were unusable due to a technical error.

Statistical approach

Our statistical approach for Experiment 2 was identical to our approach for Experiment 1. We tested six regression models, predicting either increases in stress following the social stress induction or decreases in stress following the recovery induction, as assessed using either self-report, changes in heart rate, or changes in HRV. In each model, we included FNES-, AB-, and IAT-scores (all as continuous variables), and the dummy-coded cognitive load group, as well as the interactions between load group and the explicit and implicit measures of social anxiety. Continuous variables were z-standardised prior to analysis. We tested each regression model before and after removing potential outliers. Models with and without outliers yielded similar patterns of results. In the results section below, we present the results after outlier exclusion, and we provide results of the full sample in the online supplement. We adjusted alpha levels for model significance to .025, and because each model included 7 predictors, individual predictor significance levels were adjusted to .0071 (i.e. $.05/7$).

Group characteristics, basic results, and manipulation check

Table 3 summarises the scores on all measures. As expected, the visual search task yielded a reliable AB-score. Overall, AB did not differ significantly from zero, $t < 1$, but implicit anxiety scores did, $t(69) = 15.08$, $p < .001$. The stress induction resulted in significant increases in self-reported negative mood, $t(69) = 8.03$, $p < .001$, and heart rate, $t(68) = 6.05$, $p < .001$, relative to the baseline. In a similar vein, both self-reported negative mood and heart rate decreased in the recovery phase relative to the stress induction phase, $t(69) = 10.78$, $p < .001$, and $t(66) = 6.58$, $p < .001$, respectively. For HRV, these changes were marginal, with $t(68) = 1.68$, $p = .097$, and $t(66) = 1.76$, $p = .082$, for changes following stress induction and recovery, respectively. Comparing high versus low socially anxious participants based on median-split

Table 3. Descriptive statistics of all measures in Experiment 2.

	Total Sample ^a				Low Anxious		High Anxious		<i>t</i> diff.	<i>p</i> diff.
	<i>N</i>	<i>M</i>	<i>SD</i>	Reliability ^b	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
FNES	70	17.34	10.57	.94	8.45	4.51	25.27	7.70	11.29	.00
AB (ms)	69	-0.09	361.02	.83	5.99	225.31	-5.35	449.90	0.13	.90
IAT D600	70	-0.58	0.32	.82	-0.65	0.32	-0.52	0.32	1.64	.11
Negative mood baseline	70	1.85	0.95	.77	1.60	0.73	2.07	1.07	2.14	.04
Negative mood stress	70	3.01	1.43	.93	2.59	1.13	3.39	1.57	2.42	.02
Negative mood recovery	70	1.71	0.87	.84	1.43	0.57	1.95	1.02	2.67	.01
Negative mood change (stress – baseline)	70	1.16	1.21	–	0.99	0.95	1.32	1.40	1.15	.25
Negative mood change (recovery – stress)	70	-1.30	1.01	–	-1.15	0.98	-1.43	1.03	1.17	.25
Heart rate baseline (BPM)	69	70.35	8.70	–	69.85	7.79	70.81	9.55	0.46	.65
Heart rate stress (BPM)	69	75.49	9.66	–	74.84	7.25	76.09	11.52	0.53	.60
Heart rate recovery (BPM)	67	69.45	8.36	–	69.07	7.48	69.80	9.19	0.36	.72
Heart rate change (BPM: stress – baseline)	69	5.14	7.06	–	4.99	6.38	5.28	7.73	0.17	.87
Heart rate change (BPM: recovery – stress)	67	-5.75	7.15	–	-5.49	6.54	-5.99	7.76	0.28	.72
HRV baseline	69	44.84	27.61	–	39.93	22.12	49.34	31.47	1.43	.16
HRV stress	69	42.11	24.55	–	39.45	17.71	44.54	29.53	0.86	.39
HRV recovery	67	45.31	26.91	–	40.82	23.00	49.42	29.78	1.31	.19
HRV change (stress – baseline)	69	-2.74	13.52	–	-0.48	14.05	-4.81	12.85	1.34	.19
HRV change (recovery – stress)	67	3.09	14.34	–	1.80	13.91	4.27	14.81	0.70	.48

Notes: FNES = Fear of Negative Evaluations Scale; AB = Attentional Bias; IAT = Implicit Association Test; BPM = Beats Per Minute; HRV = Heart Rate Variability. a. For correlations between measures, see Table S3 in the online supplement. b. For the FNES and negative mood scales, the reliability estimates are Cronbach's alpha. For the RT tasks, the reliability estimate is the Spearman-Brown corrected split half reliability.

FNES-scores yielded no significant differences on any of the measures, except for high anxious participants rating their negative mood higher than low anxious participants in all phases of the social stress task.

Although we had no *a priori* manipulation check for our cognitive load induction, some studies have shown that increased cognitive effort is associated with reduced HRV (e.g. Luque-Casado et al., 2016, but see e.g. also Luft et al., 2009). Comparing baseline HRV, we found no differences between the load group ($M = 43.61$, $SD = 29.63$) and the control group ($M = 46.47$, $SD = 26.76$), $t(65) = 0.42$, $p = .68$. As such, our HRV data offer no indirect support for our assumption that performing the RIR-task adds a substantial cognitive load.

Predicting social stress reactivity and recovery

Table 4 presents an overview of all the models. When predicting self-reported increase in stress from baseline to stressor (7 potential outliers excluded), the full model just reached significance, $F(7, 52) = 2.57$, $p = .023$, $R^2 = .26$, $f^2 = 0.35$. Only scores on the FNES positively predicted the increase in negative mood, and none of the crucial interaction terms were significant. The model predicting self-reported recovery from stress (8 potential outliers excluded) was not significant, $F < 1$, $p = .622$, $R^2 = .09$, $f^2 = 0.10$. In addition, none of the models predicting stress reactivity or recovery as measured by changes in either heart rate or HRV were significant (heart rate stress

reactivity – 5 potential outliers excluded: $F(7, 53) = 1.98$, $p = .075$, $R^2 = .21$, $f^2 = 0.27$; heart rate recovery – 7 potential outliers excluded: $F(7, 49) = 1.99$, $p = .075$, $R^2 = .22$, $f^2 = 0.28$; HRV stress reactivity – 3 potential outliers excluded: $F(7, 55) = 1.46$, $p = .199$, $R^2 = .16$, $f^2 = 0.19$; HRV stress recovery – 5 potential outliers excluded: $F < 1$, $p = .667$, $R^2 = .09$, $f^2 = 0.10$). In sum, we found no evidence for the hypothesis that adding a cognitive load leads to a dissociation between the capacity of implicit and explicit measures to predict social stress responses.

Discussion

The results of Experiment 2 did not confirm the hypotheses following from dual process accounts. Despite using more reliable implicit measures and assessing anxiety using also physiological outcome variables, the predictive value of explicit and implicit measures was not moderated by cognitive load. Implicit measures were not predictive of anxiety in response to a social stressor, and although the explicit measure tended to predict some anxiety responses, the cognitive load manipulation did not affect this relation.

General discussion

In two experiments, we experimentally investigated the central assumption of dual process models that implicit but not reflective processes are predictive of

Table 4. Linear regression analyses predicting changes in self-reported negative mood, heart rate, and heart rate variability in response to both social stress induction and the recovery from social stress.

Phase	Predictor	Changes in negative mood					Changes in heart rate					Changes in HRV				
		<i>B</i>	<i>SE</i>	β	<i>t</i>	<i>p</i>	<i>B</i>	<i>SE</i>	β	<i>t</i>	<i>p</i>	<i>B</i>	<i>SE</i>	β	<i>t</i>	<i>p</i>
Stress	constant	0.23	0.14		1.62	.11	0.10	0.14		0.70	.49	0.17	0.15		1.13	.26
	FNES	0.57	0.17	0.56	3.36	.00	-0.13	0.16	-0.16	0.85	.40	-0.44	0.15	-0.51	2.86	.01
	AB	-0.08	0.23	-0.06	0.34	.73	0.07	0.22	0.05	0.29	.77	0.22	0.23	0.17	0.97	.34
	IAT	0.13	0.15	0.15	0.84	.41	-0.35	0.16	-0.43	2.25	.03	0.23	0.16	0.27	1.45	.15
	Load	-0.39	0.22	-0.23	1.82	.07	-0.47	0.21	-0.29	2.28	.03	-0.10	0.22	-0.06	0.45	.65
	Load X FNES	-0.58	0.25	-0.39	2.27	.03	0.07	0.22	0.06	0.32	.75	0.40	0.23	0.32	1.76	.08
	Load X AB	0.13	0.33	0.07	0.41	.68	-0.06	0.32	-0.04	0.19	.85	-0.21	0.33	-0.11	0.63	.53
	Load X IAT	-0.36	0.23	-0.29	1.61	.11	0.49	0.21	0.44	2.28	.03	-0.25	0.22	-0.21	1.14	.26
Recovery	constant	-0.04	0.19		0.19	.85	-0.07	0.15		0.47	.64	0.01	0.14		0.06	.95
	FNES	-0.37	0.23	-0.38	1.56	.13	-0.31	0.16	-0.39	1.96	.06	0.23	0.15	0.30	1.49	.14
	AB	-0.29	0.34	-0.22	0.87	.39	-0.14	0.27	-0.12	0.51	.61	-0.14	0.21	-0.14	0.68	.50
	IAT	0.12	0.25	0.13	0.50	.62	0.39	0.16	0.52	2.44	.02	-0.19	0.15	-0.27	1.28	.21
	Load	0.24	0.25	0.14	0.95	.35	0.45	0.20	0.30	2.24	.03	-0.05	0.20	-0.03	0.23	.82
	Load X FNES	0.25	0.29	0.21	0.86	.39	0.42	0.21	0.40	1.99	.05	-0.12	0.22	-0.11	0.54	.59
	Load X AB	0.22	0.41	0.12	0.52	.60	0.20	0.34	0.13	0.60	.55	0.15	0.30	0.10	0.49	.63
	Load X IAT	-0.04	0.30	-0.03	0.12	.90	-0.46	0.21	-0.45	2.17	.03	0.24	0.20	0.24	1.17	.25

Notes: FNES = Fear of Negative Evaluations Scale; AB = Attentional Bias; IAT = Implicit Association Test; HRV = Heart Rate Variability.

behaviour when people have limited cognitive resources, while reflective but not implicit processes guide behaviour when people have plenty of cognitive resources. Contrary to this hypothesis, we found no evidence for a moderating role of cognitive load on the predictive value of implicit and explicit measures on avoidance of spiders (Experiment 1) or self-reported and physiological changes in anxiety following a social stressor (Experiment 2). We thus found no support for the idea that the predictive value of implicit versus explicit measures is moderated by the availability of cognitive resources. As such, our findings are also not in line with the findings of Effting et al. (2016), who found that WMC moderated the relation between implicit spider attitudes and avoidance of spiders. One possible explanation for these diverging results is the manner in which the availability of cognitive resources was operationalised. While Effting et al. measured WMC as an individual difference variable, we used experimental between-participants manipulations, comparing groups with versus without secondary cognitive loads. It is possible that, at least in the prediction of fear- and anxiety-related behaviours (as opposed to the prediction of appetitive behaviours, see Friese, Hofmann, & Wänke, 2008), individual differences in WMC affect the predictive value of implicit measures more than imposed cognitive load manipulations.

Another possible explanation for the lack of moderation by the cognitive load manipulations is based on differences in arousal. Dual process models specify that the likelihood of impulsive versus reflective processes driving behaviour depends not only on cognitive load, but also on arousal (Strack & Deutsch, 2004). The predictive power of impulsive processes is thought to peak at low and very high levels of arousal, while at intermediate levels of arousal, reflective processes are assumed stronger. In Experiment 1, participants approached the spider on average up to 37cm, while in Experiment 2, the stress induction on average resulted in a 1-point increase in negative affect on a 7-point scale. Thus, considering our outcomes as moderately arousing, reflective processing may have been strengthened in both groups, possibly overriding any effects of the load manipulation.

Apart from the absence of moderation by the cognitive load manipulations, our experiments also failed to mirror the results of several earlier studies addressing the role of implicit measures in predicting behaviour. For instance, while implicit measures have been

argued to be a useful addition to explicit measures in the prediction of fear- and anxiety-related behaviours (de Hullu et al., 2011; Egloff & Schmukle, 2002), our data suggest that this is not necessarily the case. In our experiments, only explicit measures predicted anxiety-related outcomes. We also found no evidence for the idea that implicit measures are especially predictive of physiological fear responses (Huijding & de Jong, 2006; Van Bockstaele et al., 2011). However, the idea that explicit measures are predictive of more controlled behaviours and implicit measures are predictive of outcomes that are difficult to control does not take into account the potential interactions between impulsive and reflective processes (Ouimet, 2017; Strack & Deutsch, 2004), with impulsive processes influencing reflective processes and vice versa. Finally, we found no differences between high and low spider fearful or socially anxious groups on any of the implicit measures. As such, our results further illustrate that AB for threat is probably a less consistent finding than what is generally assumed (Van Bockstaele et al., 2014). Also regarding automatically activated associations, past research has yielded mixed findings, with some studies showing significant differences between high and low anxious groups, and other studies finding no evidence for such differences (for reviews see Roefs et al., 2011; Teachman et al., 2019). Our current results further demonstrate that – despite the popularity of implicit measures – effects in this field may be smaller or less consistent than what is generally assumed.

While our primary focus was on the effects of cognitive load on the predictive value of implicit measures, effects of cognitive load on spider avoidance (Experiment 1) or social stress reactivity (Experiment 2) also add to the broader literature on the relation between cognitive load and anxiety. Previous studies have shown that cognitive load can hamper extinction learning (Raes et al., 2009) and that people with high working memory ability show more fear extinction than people with low working memory ability (Stout et al., 2018). In contrast, it has also been found that increased cognitive load can help to reduce anxiety (Vytal et al., 2012). Post-hoc independent samples *t*-tests comparing high and low load groups in spider avoidance and social stress reactivity revealed significant group differences in the self-reported and heart rate indices of stress reactivity of Experiment 2, $t(66) = 2.13, p = .04, d = 0.52$ and $t(49.94) = 3.02, p = .004, d = 0.73$, respectively; all other $t_s < 1$, all other p_s

>.34. Participants in the no load group had a stronger increase in self-reported negative mood ($M = 1.45$, $SD = 1.25$) and heart rate ($M = 7.51$, $SD = 8.47$) than participants in the load group (self-reported negative mood: $M = 0.84$, $SD = 1.10$; heart rate: $M = 2.67$, $SD = 4.08$), indicating that, even though these results are preliminary, cognitive load reduced social stress reactivity.

An important issue concerns the theoretical framework underlying dual process models. Although these models have inspired research, they have also been criticised (e.g. Keren & Schul, 2009; Melnikoff & Bargh, 2018), in particular with regard to the coherence of the automaticity characteristics of impulsive versus reflective processes. Dual process models for instance assume that impulsive processes are unconscious and unintentional, but Melnikoff and Bargh provide examples of unconscious phenomena that do require a level of intention (e.g. driving a car), indicating that the automaticity characteristics of implicit processes are not coherent and mutually exclusive. While instead of dual-process models also a unitary model has been proposed (Hommel & Wiers, 2017), even this unitary model involves a (meta-)control component that gives rise to the same moderation hypothesis as the one we tested in our current study. In other words, regardless of whether one adheres to dual process models or unitary models with a control component, processes that have more or stronger features of automaticity are still hypothesised to be more predictive of behaviour when cognitive control is weak or when cognitive resources are depleted. In both of our experiments, we found no support for this hypothesis.

Our study also has limitations. While memorising digits (Experiment 1) is often used as a procedure to induce cognitive load (e.g. Friese, Hofmann, & Wänke, 2008), and the RIR task (Experiment 2) is a well-validated procedure taxing the central executive (Vandierendonck et al., 1998), it is possible that our load manipulations were relatively weak. In Experiment 1, the effect of memorising digits on our flanker task manipulation check was limited to a general slowing of RTs, and in Experiment 2, we did not include an a priori manipulation check to assess the extent to which the secondary RIR-task imposed a cognitive load. Including convincing manipulation checks and using more cognitively demanding secondary tasks, requiring more active, deliberate

processing and/or requiring the same sensory modality as the primary task, may either strengthen our findings or yield different results. Another limitation concerns our sample sizes and the achieved statistical power. Although we had sufficient power to detect effects with $f^2 = 0.23$ and larger, and we had ample power to detect effects as large as those reported by Friese, Hofmann, and Wänke (2008), we lacked statistical power to detect smaller effects. Finally, in the different implicit measures in Experiment 1, participants were repeatedly exposed to pictures of spiders. We cannot rule out that participants became increasingly more habituated to these pictures, which may have reduced the size of possible effects in the dot probe task and the attentional disengagement task (i.e. the tasks that were completed later in the procedure).

In conclusion, in two experiments, we found no empirical support for the central assumption of dual process models that the availability of cognitive resources moderates the predictive value of implicit and explicit measures. Pending follow-up studies with demonstrably effective cognitive load manipulations, our results suggest that, despite their intuitive appeal and frequent use in explaining behaviour, the foundations of these models should be either reformulated or solidified by more extensive empirical work.

Notes

1. More detailed power analyses are provided in the online supplement.
2. This regression model violated the assumption of independent errors (Durbin-Watson = 0.82), indicating that it may not generalise beyond our sample.
3. More detailed power analyses are provided in the online supplement.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Open practice and data availability statement

Neither of the experiments reported in this article was formally preregistered. The original scripts (excluding copy-righted stimulus materials), raw data, descriptions of data transformations, transformed data, outlier analyses, and results that were used in both experiments are accessible in the following OSF data depository: doi:10.17605/OSF.IO/9XFCD.

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