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Expectancy Biases in Fear and Anxiety and Their Link to Biases in Attention

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Abstract

Healthy individuals often exhibit prioritized processing of aversive information, as manifested in enhanced orientation of attention to threatening stimuli compared with neutral items. In contrast to this adaptive behavior, anxious, fearful, and phobic individuals show exaggerated attention biases to threat. In addition, they overestimate the likelihood of encountering their feared stimulus and the severity of the consequences; both are examples of expectancy biases. The co-occurrence of attention and expectancy biases in fear and anxiety proposes causal influences. Herein, we summarize findings related to expectancy biases in fear and anxiety, and their association with other processing biases, focusing on the link with attention biases. We suggest that evidence calls for more comprehensive research strategies in the investigation of mutual influences between expectancy and attention biases, as well as their combined effects on fear and anxiety. Moreover, both types of bias need to be related to other types of distorted information processing commonly observed in fear and anxiety (e.g., memory and interpretation biases). Finally, we propose new research directions that may be worth considering in developing more effective treatments for anxiety disorders.

Keywords: fear, phobia, anxiety, threat, expectancy bias, attention bias, combined bias hypothesis

Expectancy Biases in Fear and Anxiety and Their Link to Biases in Attention

Fear is an essential emotion for survival because it ensures adaptive reactions in dangerous situations (e.g., Bradley & Lang, 2007; Öhman & Mineka, 2001). Yet, despite the existential importance of sensitivity to threat, for some people, fear (and its more chronic and less stimulus-oriented form, anxiety) can also lead to overprotective responses such as the complete avoidance of situations associated with the feared threat. Such maladaptive behavior may originate in deviated information processing, making those individuals experience the situation as more dangerous than it actually is (for examples of cognitive theories elaborating such ideas, see Beck, Emery, & Greenberg, 1985; Mathews & MacLeod, 1994; J. M. G. Williams, Watts, MacLeod, & Mathews, 1997).

Fear and phobia are characterized by robust and consistent expectancy biases. Highly fearful and phobic individuals exhibit higher expectancies of encountering threat (Aue & Hoeppli, 2012; de Jong & Muris, 2002), as well as higher expectancies that such encounters will have aversive consequences (Amrhein, Pauli, Dengler, & Wiedemann, 2005; Kennedy, Rapee, & Mazurski, 1997; Mühlberger, Wiedemann, Herrmann, & Pauli, 2006). Whereas other kinds of cognitive distortions in anxiety have been more extensively studied, biases in expectancies, to date, have rarely been systematically examined and are therefore in the focus of the present article.

In addition to distorted expectations, anxious and phobic individuals exhibit other cognitive biases. For instance, there is evidence of diverse attention biases toward threat, especially among anxious and fearful or phobic individuals (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendorn, 2007). Of note, recent work postulates a causal role for attention biases in the development of anxiety, similarly to its proposed role in depression (e.g., Harmer, Goodwin, & Cowen, 2009; Watters & Williams, 2011), a psychopathology that is simultaneously characterized by dysfunctional expectations.

Investigating potential links between the less investigated expectancy biases and the more prominent attention biases is compelling. Yet, to date, research focusing on both healthy and pathological forms of fear has overlooked possible relations between expectancy and attention biases (and other types of cognitive biases, including biases in memory and interpretation). Considering the comorbid appearance of these biases in fear and anxiety, it is plausible to hypothesize common underlying mechanisms (for related ideas, c.f. Mathews, Mackintosh, & Fulcher, 1997; J. M. G. Williams et al., 1997). Notably, most cognitive models of psychopathology postulate that information-processing biases exert influences on one another (e.g., Ingram, 1984; J. M. G. Williams et al., 1997).

Revealing causal relations between maladaptive cognitive processes in anxiety may have significant theoretical and clinical implications: From a basic scientific point of view, understanding the causal relations of different cognitive biases may shed light on the underlying mechanisms in health and disease states. Moreover, therapeutic approaches targeting (the) causal mechanism(s) in anxiety may be more effective than current treatments. The present review paper, therefore, focuses on deviations in expectancies and their causal interplay with altered attentional processes.

Focusing our review on links of expectancy bias with other biases on those in attention has two reasons. First, as we write, attention biases have been extensively investigated in fear and phobia but also in healthy controls. Research has shown that attention biases are important building blocks of fear and anxiety. Therefore, the investigation of links between expectancy and attention distortions can revert to an important knowledge base. Second, as we will outline later, to date, empirical data regarding causal relations between expectancy bias and other cognitive distortions exist exclusively with respect to attentional phenomena.

We first consider the characteristics of expectancy and attention biases and how these can be conceptually distinguished from other types of bias that have additionally been observed in fear and phobia. Next, we provide short summaries[1] of research conducted on expectancy and attention biases to fear-evoking stimuli among (a) healthy, (b) anxious[2], and (c) fearful[3] or phobic[4] adults (see Salum et al., 2013; Shechner et al., 2012, for biases in children and adolescents). We differentiate these populations to examine possible similarities and differences between healthy and pathological reactivity to threat. We then describe theoretical considerations and recent work investigating the

[1] This summary is partial, particularly with respect to attention biases that have already been investigated in numerous studies (see Yiend, 2010, for a more detailed review).

[2] If not otherwise indicated, the terms "anxious" and "anxiety" in this paper refer to individuals who display mostly subclinical fear and apprehension across a variety of situations (generally assessed via questionnaires; e.g., the State-Trait Anxiety Inventory; Spielberger, Gorsuch, & Lushene, 1970).

[3] In this paper, the term "fearful" refers to individuals who exhibit extreme fear toward a specific category of threat, but who were not clinically diagnosed as phobic.

[4] In contrast, in the context of the present paper, the term "phobic" refers to individuals who were clinically diagnosed (e.g., using the *Diagnostic and Statistical Manual of Mental Disorders* [5th ed., American Psychiatric Association, 2013] or the *International Classification of Diseases and Related Health Problems* [10th rev., World Health Organization, 1992] diagnostic criteria).

relation between expectancy and attention biases to threat. Finally, we discuss the need to add other types of bias (such as memory and interpretation bias) to the investigation of expectancy-attention links in fear and phobia. Supplemental consideration of these complementary distortions in information processing may help to shed light on the concrete mechanisms underlying expectancy-attention links. Our reflections ought to inspire future research in the field, thereby helping to uncover mechanisms that establish and strengthen nonadaptive symptoms in anxiety disorders.

Definitions of Expectancy Bias, Attention Bias, and Other Forms of Distorted Information Processing

Expectancy Bias

It is important to distinguish two different types of biased expectations (Aue & Hoeppli, 2012; Foa & Kozak, 1986). Catastrophic thinking in exaggerated fear, phobia, and anxiety may result both from overestimating the likelihood of *facing* an anticipated threat source (*encounter expectancy bias*; referred to as *probability* by Foa & Kozak, 1986) and from overestimating the likelihood that such a confrontation with the threat source will have *severe consequences* (*consequences expectancy bias*; referred to as *cost* by Foa & Kozak, 1986). Although such a distinction may seem trivial, it is critical because these two types of expectancy bias should influence different aspects of subjective fear. Encounter expectancy bias should refer to the likelihood of the occurrence of fear episodes (i.e., the *frequency* of occurrence). Conversely, consequences expectancy bias should refer to fear *intensity* (see McNally & Heatherton, 1993, Experiment 1, for supportive evidence).

The surprisingly sparse research on distorted expectations in fear includes investigations of so-called *expectancy bias* and *covariation bias.* Although at first glance these terms seem divergent, they refer to highly similar phenomena. Studies on expectancy bias used on-line investigations of expectancies of negative outcomes while individuals were presented with certain classes of stimuli, such as snakes and spiders (e.g., Amin & Lovibond, 1997; Davey, 1992; Davey, 1995; de Jong, Merckelbach, & Arntz, 1995; Diamond, Matchett, & Davey, 1995; Honeybourne, Matchett, & Davey, 1993).

Studies on covariation bias, in contrast, assessed illusory correlations between certain classes of stimuli and outcomes (such as between spiders or snakes and pain) in the absence of external stimulus presentations (e.g., McNally & Heatherton, 1993; Tomarken, Mineka, & Cook, 1989). Moreover, the term covariation bias mixes two different phenomena, an *a priori covariation bias* and an *a posteriori covariation bias*. The a priori covariation bias can be considered an off-line expectancy bias (e.g., Davey, 1992 [preconditioning stage]; McNally & Heatherton, 1993; for an overview, see Davey, 1995, or Davey & Dixon, 1996). Specifically, a priori covariation bias describes the tendency to expect greater aversive consequences from fear- or phobia-relevant stimuli than from fear- or phobia-irrelevant stimuli (e.g., greater expectancy to receive an electric shock after having viewed spiders than after having viewed flowers) and is generally assessed before the onset of an experiment. The a posteriori covariation bias, instead, is assessed at the end of an experiment and describes the same association in retrospect, namely, that humans have a tendency to overassociate previous events that were related to fear-relevant stimuli with past negative experiences (e.g., de Jong & Merckelbach, 1991; de Jong, Merckelbach, Arntz, & Nijman, 1992; Pury & Mineka, 1997; Tomarken et al., 1989; Tomarken, Sutton, & Mineka, 1995). Consequently, we consider the a posteriori covariation bias as a memory bias and will not discuss it in the context of expectancy biases (for a meta-analytic review on memory biases, see Mitte, 2008; for a review specifically on social phobia, see Hirsch & Clark, 2004).

As described earlier, the difference between expectancy bias and a priori covariation bias refers to the transient presence versus absence of external stimuli that individuals associate with negative outcomes. Yet, because studies on covariation bias rely on internal representations of the stimuli, the distinction seems minor. An additional difference, however, is that covariation bias is often assessed off-line in single-trial snapshots before (or after; i.e., memory bias) the experimental manipulations, whereas expectancy bias relies more strongly on multiple-trial on-line assessments of expectancies in an experiment. In the following, therefore, we use the terms on-line and off-line expectancy bias.

Attention Bias

These biases comprise (a) early automatic vigilance in the face of threat (Mogg & Bradley, 1998), (b) difficulty in disengaging attention from threat (Cisler & Koster, 2010; Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Yiend & Mathews, 2001), and (c) avoidance of threatening information during later, more controlled, stages of processing (corresponding to the so-called vigilance-avoidance pattern; see Amir, Foa, & Coles, 1998; Mogg, Bradley, DeBono, & Painter, 1997).

Additional Types of Information Processing Bias

Anxiety and fear are characterized by other kinds of processing biases in addition to expectancy and attention biases. Because the use of terminology referring to these different kinds of distortions generally lacks consistency, the following differentiation of some of these terms from expectancy bias relies on our own definitions of these phenomena.

Memory bias describes the tendency to recall information and past experiences in a distorted manner, whereas expectancy bias is directed toward future happenings (see distinction between a priori and a posteriori covariation biases earlier). *Interpretation bias* refers to the tendency of an individual to interpret ambiguous situations in either a positive or a negative way; these situations usually relate to the present rather than to the future. *Attribution bias* is related to inferences about the causes of human behavior or significant happenings and is therefore oriented toward the past. Rather than being concerned with such causes, expectancy bias is future oriented (i.e., related to anticipated outcomes and their implications for personal well-being). Finally, *reasoning bias, belief bias,* or *confirmation bias* (also termed motivated reasoning) relates to the fact that we sometimes specifically search for evidence supporting our own convictions or weigh evidence in a distorted fashion. Such behavior serves the confirmation of existent belief systems and reduces cognitive dissonance. Therefore, confirmation bias may rely on the activation of related biases in expectancies and attention. Notably, as we outline in greater depth later, although we believe it is important to consider the biases as separate from each other, evidence suggests that these different types of information-processing biases exert mutual influences.

Review of Research on Expectancy Bias

Whether or not we anticipate the possibility of being confronted with a threatening situation in the near or far future should have a major impact on our experience of fear.[5] Despite these considerations, biased expectancies in fear and phobia have rarely been systematically investigated and are therefore reviewed in detail here. Table 1 provides a summary of the findings for the populations considered. Figure 1 shows how different types of expectancy bias have been investigated in the research reviewed.

Healthy Individuals

In studies of off-line expectancy bias toward negative consequences in which participants were told that electric shocks would be administered after fear-relevant (e.g., dangerous animals such as snakes and spiders) and fear-irrelevant (i.e., nonthreatening animals such as cats and pigeons) stimuli, healthy participants initially expected more shock administrations after fear-relevant stimuli than after fear-irrelevant stimuli (e.g., Diamond et al., 1995; Honeybourne et al., 1993; Kennedy et al., 1997; McNally &

[5] In fact, some theories see fear and anxiety as a result of a maladaptive or unfortunate learning history (related to classical conditioning, instrumental conditioning, or observational learning; Bandura, 1977; Mowrer; 1956, Rachman, 1977), thus producing distorted expectancies that are expressed in catastrophizing thoughts. This view comprises the idea that such disadvantageous expectancies can be unlearned (see Myers & Davis, 2002, for mechanisms underlying fear extinction), a conviction that is also expressed in (cognitive) behavior therapy (Beck, 1976; Butler, Fennell, & Hackmann, 2008), which targets these maladaptive expectancies in fear and anxiety by cognitive reframing methods and exposure in vivo and/or in sensu.

Heatherton, 1993). These initially anticipated contingencies were disconfirmed when subsequently no shock was administered at all. As such nonreinforcement of the a priori biased expectancies continued, the overestimation of negative consequences of fear-relevant as compared with fear-irrelevant stimuli (on-line expectancy bias for negative consequences) vanished (Amin & Lovibond, 1997; Davey, 1992). Yet, a single pairing of a fear-relevant stimulus with an electric shock can reinstate the consequences expectancy bias (Davey, 1992). Moreover, biased consequence expectancies have been reported to go hand in hand with increased skin conductance response magnitudes at some moments during an experiment (e.g., Amin & Lovibond, 1997; Davey, 1992; Diamond et al., 1995; Honeybourne et al., 1993).

Whether observed consequence expectancy biases toward phylogenetic threats such as snakes and spiders are more pronounced than are such biases toward ontogenetic threats (e.g., weapons and broken outlets) needs to be further investigated. Although there is evidence for a stronger expectancy bias for phylogenetic threats (Amin & Lovibond, 1997), other researchers found no difference between phylogenetic and ontogenetic threats (Honeybourne et al., 1993; McNally & Heatherton, 1993).[6]

Finally, a study of on-line encounter expectancy bias (Aue & Hoeppli, 2012) found no evidence among healthy controls for overestimation of encounters with fear-relevant animals (spiders and snakes) compared with birds. Notably, however, all participants included in this research displayed very low levels of fear of both spiders and

[6] This mixed evidence mirrors the results observed in the area of attention bias (supportive evidence for priority of phylogenetic threat: e.g., Öhman, Flykt, & Esteves, 2001; contradictory evidence: e.g., Lipp, Derakshan, Waters, & Logies, 2004; Tipples, Young, Quinlan, Broks, & Ellis, 2002).

snakes. Further research is thus needed to draw conclusions as to the existence of an encounter expectancy bias in healthy individuals.

Anxious Individuals

There is evidence that anxious individuals show pronounced distortions in expectancies. Butler and Mathews (1983) observed that patients with generalized anxiety disorder exhibited higher estimations of the likelihood that unpleasant events would occur than did nonanxious controls (i.e., off-line encounter expectancy bias). Conversely, no difference was found between individuals marked by high anxiety and those marked by low anxiety in their likelihood estimations for pleasant events.[7] More research is needed, however, before definitive conclusions can be drawn. To the best of our knowledge, research on the consequences expectancy bias in anxiety is still lacking.

Fearful and Phobic Individuals

Expectancy biases are common in phobia. For instance, social phobics appear to overestimate the negative consequences of negative social events (Foa, Franklin, Perry, & Herbert, 1996; McManus, Clark, & Hackmann, 2000). Related effects have been observed in fears that are unrelated to social events.

Mühlberger et al. (2006) showed pictures of spiders, flight accidents, and mushrooms to spider-phobic and flight-phobic participants. These pictures were followed by startling noises in some instances. Before the beginning of the experiment, participants with spider phobia and those with flight phobia reported an off-line a priori consequences

[7] This study was not published under the terms expectancy bias or covariation bias. Instead, the authors used the term *judgmental bias*.

expectancy bias for their respectively feared stimuli (see Amrhein et al., 2005, for comparable results for panic-prone individuals, as well as Kennedy et al., 1997, for comparable results for individuals characterized by high fear of spiders, of snakes, and of damaged or exposed electrical outlets). This a priori bias disappeared at the end of the experiment (no a posteriori covariation or memory bias; see also Amrhein et al., 2005).[8] Nevertheless, this initial bias disappeared much more slowly among those with spider phobia than among those with flight phobia, thus supporting the notion of the organism's biological preparedness for phylogenetic threat stimuli (for similar evidence, see de Jong et al., 1995).[9] Consistent with this finding, spider phobia, in contrast to flight phobia, was associated with enhanced skin conductance responses, magnitude of event-related brain potentials, and startle amplitudes, as reported by Mühlberger et al. (2006).

Some studies have shown that fear level may vary as a positive function of the magnitude of the consequences expectancy bias (e.g., de Jong et al., 1995; Diamond et al., 1995; but see Amin & Lovibond, 1997, for counter-arguments). Furthermore, Muris,

[8] But see Kennedy et al. (1997) for surviving effects in individuals who are highly fearful of spiders, snakes, and damaged or exposed electrical outlets. The divergent results of these studies may be related to differences in task, population, and experiment duration.

[9] Other research shows that among panic-prone individuals, the unlearning of illusory correlations between fear-relevant stimuli and aversive consequences can be accelerated by establishing high contingency between fear-irrelevant stimuli and aversive outcomes and low contingency between fear-relevant stimuli and aversive outcomes (e.g., by more frequently presenting fear-irrelevant stimulus–electric shock pairings than fear-relevant stimulus–electric shock pairings; Pauli, Montoya, & Martz, 2001). Such a procedure resembles the manipulations used in attention bias modification (ABM) procedures (see following section).

Huijding, Mayer, den Breejen, and Makkelie (2007) reported that fearful individuals, in addition to overestimating the negative consequences of the presentation of a feared animal, underestimated the likelihood of positive consequences (e.g., likelihood of obtaining candy). Hence, both the direction and the magnitude of bias should be explicitly addressed.

Evidence further indicates that, apart from biased consequence expectancies, phobias are characterized by pronounced biases in encounter expectancies.[10] Consistent off-line encounter expectancy biases have been reported for social phobia. Specifically, social phobics have been observed to overestimate the likelihood of being personally confronted with negative social events (Foa et al., 1996; Gilboa-Schechtman, Franklin, & Foa, 2000; Lucock & Salkovskis, 1988; possibly restricted to situations regarding personal performance: McManus et al., 2000), while underestimating the likelihood of being confronted with positive social events (Gilboa-Schechtman et al., 2000; Lucock & Salkovskis, 1988). Off-line encounter expectancy biases have also been observed in agoraphobia (McNally & Foa, 1987) and acrophobia (Menzies & Clarke, 1995). Moreover, these biases were disorder-specific and did not extend to nondisorder-related areas (e.g., social versus nonsocial events in social phobia; Foa et al., 1996; Lucock & Salkovskis, 1988).

Fear of spiders has also been associated with exaggerated on-line expectancies of encounters (e.g., spiders entering a room or spiders making physical contact; de Jong & Muris, 2002 [in spider-phobic children], or spiders appearing in a movie; Wik, Fredrikson, & Fischer, 1996). Moreover, we (Aue & Hoeppli, 2012) were able to show that such exaggerated expectancies cannot be eliminated by giving objective background information, suggesting overall high or low probabilities of confrontations (for neuroimaging data suggesting reduced cognitive control being at the root of distorted encounter expectancies, see Aue et al., 2015).

Notably, both types of expectancy bias diminished or even extinguished after effective treatment of social phobia (e.g., Foa et al., 1996; Lucock & Salkovskis, 1988; McManus et al., 2000). Patients in the Foa et al. (1996) study, for instance, underwent comprehensive cognitive-behavioral therapy for generalized social phobia. This therapy comprises exposure, cognitive restructuring, and social skills training. Lucock and Salkovskis (1988) used related techniques such as thought monitoring, reality testing, and activity scheduling, as well as challenging and looking for alternatives to negative automatic thoughts. To what degree each of these treatment components has been causally involved in the reduction of the expectancy biases remains to be determined. The development of specific cognitive bias modification (CBM) trainings, those that focus on individual expectancies, might be helpful in that respect.

Interim Summary: Expectancy Bias

Current research suggests the existence of diverse kinds of threat-related expectancy biases (on- and off-line consequences bias; on- and off-line encounter expectancy bias) among anxious, fearful, and phobic individuals (Table 1). The findings are surprisingly robust (across disorders, experimental manipulations, and measurement points). Therefore, biased expectancies may constitute a core characteristic of anxiety disorders. Yet, evidence for anxious individuals is sparse regarding biases both in encounter and in consequences expectancies, and, to the best of our knowledge, subclinical populations have not yet been examined.

Evidence among healthy individuals, in contrast, is mixed. No encounter expectancy bias was reported among these individuals, but an a priori bias for consequences may exist for threat emanating from evolutionarily salient stimuli such as snakes and spiders. Yet, biased expectancies are weaker in healthy individuals than in phobics and can be more readily overcome by refuting information. Because threat-related encounter expectancy biases in healthy individuals have only rarely been studied, future research is needed before safe conclusions can be drawn.

Review of Research on Attention Bias

In contrast to biased expectancies, attentional biases have been extensively studied and therefore are only partially reviewed here. Table 2 provides a summary of the evidence regarding different attention biases in healthy, anxious, fearful, and phobic individuals. Figure 2 displays the most prominent paradigms used in examining attention biases in fear and anxiety.[11] The specific cognitive and neural mechanisms underlying these biases are still being debated (for discussion, cf. Heeren, De Raedt, Koster, & Philippot, 2013).

Healthy Individuals

Some evidence exists for attention biases toward threat. For instance, nonfearful participants are characterized by greater facility in detecting a spider or a snake among

[11] An alternative way to measure attention biases is to assess eye movements via eye tracking (e.g., Aue, Hoeppli, Piguet, Sterpenich, & Vuilleumier, 2013).

mushrooms or flowers than vice versa. This facility may be due to biological preparedness for processing survival-relevant stimuli (Öhman et al., 2001; but see Lipp et al., 2004; Tipples et al., 2002). Attention bias toward threatening stimuli has also been demonstrated for other materials, including pictures of mutilated faces (Koster, Crombez, Verschuere, & De Houwer, 2004), words related to physical or social threat (Mogg et al., 1997), and angry faces (Brosch, Sander, Pourtois, & Scherer, 2008).

Although these findings are suggestive, in a meta-analysis of 172 studies that used different paradigms, Bar-Haim et al. (2007) did not find evidence for an attention bias toward or away from threat in healthy individuals. Enhanced engagement of attention in threat was revealed only in blocked-design emotional Stroop task, which may rely on the accumulated exposure producing greater perceived threat. Such an interpretation is in line with evidence that nonanxious individuals show attention biases only when presented with high levels of threat (Mogg & Bradley, 1999; Wilson & MacLeod, 2003).

Nevertheless, the meta-analysis by Bar-Haim et al. (2007) relied solely on reaction time (RT) data related to the more traditional paradigms used in research on attention bias (see Figure 2). Other measures may be more sensitive to biases in healthy individuals.[12] Our own (Aue, Hoeppli, et al., 2013) eye tracking and neurophysiological data suggest that emotional arousal may guide visual attention to potential threat sources, thus increasing vigilance to spiders even among nonfearful individuals. Such a mechanism may help healthy individuals actively cope with a threatening situation in order to downregulate emotional arousal.

[12] Note as well that visual search paradigms were not included in Bar-Haim et al.'s meta-analysis.

Anxious Individuals

Whereas evidence for attention biases in healthy individuals is mixed, attention bias effects in anxious, fearful, and phobic individuals are more robust (Table 2; see also next section). In the earlier-mentioned meta-analysis, Bar-Haim et al. (2007) found a bias toward threat among anxious individuals. This effect persisted across paradigms, stimuli, populations, and exposure durations. In a recent literature review, Cisler and Koster (2010) concluded that anxious individuals exhibit facilitated attention engagement under threat, as well as difficulty in disengaging from threat, and attentional avoidance of threat (see also Fox et al., 2001, 2002; Richards, Benson, Donnelly, & Hadwin, 2014; for a critical review of current paradigms, see Clarke, MacLeod, & Guastella, 2013). Several studies further demonstrate the importance of considering the unfolding of attention over time, suggesting a vigilance-avoidance type of response to threat in anxious individuals (Ellenbogen & Schwartzman, 2009; Koster, Crombez, Verschuere, Van Damme, & Wiersema ,2006; Mercado, Carretie, Hinojosa, & Penacoba, 2009).

CBM procedures have been rapidly developed in recent years.[13] The main aim of developing these techniques is to examine the causal role of different processing biases in the maintenance of anxiety symptoms (see review in MacLeod & Mathews, 2012). In

[13] Here, we briefly summarize some of the main findings derived from works that use CBM paradigms. For CBM in children and adolescents, see detailed reviews in Bar-Haim, 2010; Beard, 2011; Browning, Holmes, & Harmer, 2010; Lowther & Newman, 2014; and MacLeod & Mathews, 2012. For meta-analyses, refer to Hakamata et al., 2010; Hallion & Ruscio, 2011; Pergamin-Hight et al., 2015. See also Clarke, Notebaert, & MacLeod, 2014, who discuss null findings for CBM and suggest possible reasons.

attention bias modification (ABM) paradigms, individuals are trained to focus their attention on neutral rather than threatening stimuli. Numerous studies have shown the effectiveness of ABM procedures in correcting stable pathological, nonadaptive attention patterns in anxiety, with effect sizes similar to existing treatments (see meta-analysis of Pergamin-Hight, Naim, Bakermans-Kranenburg, van IJzendoorn, & Bar-Haim, 2015). The overall success of CBM techniques supports the view that processing biases have a causal role in symptoms of anxiety.

In line with the idea that deficits in attention control underlie changes following ABM, event-related potential findings suggest that ABM affects top-down attention control mechanisms, and not early attention-orienting mechanisms (Eldar & Bar-Haim, 2010; Koster, Baert, Bockstaele, & De Raedt, 2010; for evidence regarding the neural pathways associated with ABM changes, see Browning, Holmes, Murphy, Goodwin, & Harmer, 2010; Clarke et al., 2014; Eldar & Bar-Haim, 2010).

Fearful and Phobic Individuals

Similar to anxious individuals, individuals with specific phobias exhibit biased attention toward their phobic stimuli, both regarding facilitated engagement and failure to disengage early attention from the threat (e.g., for social phobia, see Becker, Rinck, Margraf, & Roth, 2001; for spider and snake phobia, see Cisler, Ries, & Widner, 2007; Gerdes, Alpers, & Pauli, 2008; Lipp & Derakshan, 2005; Michalowski et al., 2009; Mogg & Bradley, 2006; Okon-Singer, Alyagon, Kofman, Tzelgov, & Henik, 2011; Pflugshaupt et al., 2005; Vrijsen, Fleurkens, Nieuwboer, & Rinck, 2009; Wik et al., 1993; see review in Okon-Singer, Lichtenstein-Vidne, & Cohen, 2013).

As in the case of anxiety, there is evidence for a vigilance-avoidance behavior pattern in phobia (e.g., Rinck & Becker, 2006). Recent eye tracking and neurophysiological data suggest that (a) the avoidance of phobic content among phobic individuals originates in heightened activity in the fear circuit; (b) in contrast to healthy individuals, these individuals engage in visual avoidance to downregulate fear; and (c) they use visual avoidance because they cannot successfully apply other regulation strategies (Aue, Hoeppli, et al., 2013).

In two randomized controlled studies on generalized social phobia, ABM led to significant symptom reduction both after training and at 4 months follow-up (Amir et al., 2009; Schmidt, Richey, Buckner, & Timpano, 2009). ABM with spider phobics, on the other hand, was associated with a temporary decrease in attention bias, but not with a greater reduction of symptoms (Reese, McNally, Najmi, & Amir, 2010). The latter findings may suggest that exposure to an ABM procedure alone is not sufficient to overcome strong and enduring symptoms of fear in specific phobia. Since multiple biases (e.g., in attention and in expectancies) coexist and interact, it is possible that changing pathological attentional processing solely is insufficient.

Interim Summary: Attention Bias

The body of research on attention bias in fear and in phobia points to enduring vigilance-avoidance patterns with respect to threat. Such patterns are difficult to modify and may result in severe disruption of everyday life. Evidence indicates that anxious, fearful, and phobic individuals show an initial facilitated attention bias toward threat, followed by difficulty in disengaging and later by avoidance during more controlled stimulus processing. These observations point to fundamental differences in the distribution of attention in the face of threatening material among anxious, fearful, and phobic individuals compared with that among healthy individuals. ABM procedures have been developed to correct pathological attentional patterns in anxiety and phobia.

Research Linking Biases in Expectancies and Attention

To date, research on both healthy and pathological forms of fear has largely disregarded possible relations between expectancy and attention biases. We will start with some theoretical considerations about a link between diverse kinds of information-processing biases in fear and anxiety. We will then describe some first studies investigating associations between distortions in expectancy and attention and discuss their implications. We will conclude this section with an additional consideration of other types of bias observed in fear and phobia, which may shed light on the mechanisms underlying expectancy-attention links.

Theoretical Considerations

Mathews et al. (1997) proposed that an automatic threat evaluative system affects an individual's distribution of attention to threatening—often distracting—stimulations. The stronger an initial perceptual representation of an emotional distractor (in working memory), the harder and more effortful it should be to control and redirect attention toward nonthreatening cues. According to such a view, perceptual and memory processes have a strong impact on attentional processes in fear.[14] Recent theoretical perspectives further developed the idea of such interdependencies between cognitive biases.

[14] Related to this idea, we (Arend, Henik, & Okon-Singer, 2015) recently reviewed lesion studies and suggested that emotional tagging may influence information processing via working memory mechanisms

According to the *combined cognitive bias hypothesis* (Hirsch, Clark, & Mathews, 2006; see also J. M. G. Williams et al., 1997), cognitive biases (e.g., in attention, interpretation, and negative self-imagery) rarely act in isolation. Instead, they are supposed to be characterized by mutual influences on each other. In addition to these mutual influences, a given bias is hypothesized to be capable of moderating the impact of another bias on experienced fear. Uncovering such interplays between different biases could thus have ground-breaking consequences for the understanding of anxiety disorders. Although expectancy bias has so far been ignored in these considerations, this theoretical perspective can easily be extended to distortions in expectancies.

In fact, models of visual detection consider prior expectancies and working memory representations to be causal factors implicating visual search (i.e., visual attention). For instance, attentional engagement theory (Duncan & Humphreys, 1989) postulates that attentional selection is modulated by templates that are actively maintained in memory (for highly similar hypotheses put forth by the guided search model, see Wolfe, 2003, 2010; Wolfe, Butcher, Lee, & Hyle, 2003; see also Kiyonaga, Egner, & Soto, 2012, regarding cognitive control over working memory biases related to selective attention, and Olivers, Peters, Houtkamp, & Roelfsema, 2011, for the conditions under which working memory content does or does not influence selective attention). These theories predict shifts of attention in case a sensory input matches a set of predefined properties.

in healthy individuals. Similar mechanisms may lead to biased processing in anxiety, assuming abnormal initial evaluations of stimuli.

Applied to anxiety disorders, anxious individuals may, for instance, be predicted to expect situations that they consider risky as likely to occur and possibly to activate corresponding memory contents. These expectancy-triggered changes may, in consequence, increase vigilance toward threatening signals in the internal and external environments. Expectancy biases, then, may be the cause of observed biases in attention. On the other hand, the reverse influence is also imaginable, namely, that pathological attention to threatening information, possibly mediated by increases in threat-related cognitions (e.g., interpretations, memories), shapes biased expectancies. These examples show that the interplay between expectancy biases and other forms of bias in fear and phobia deserves greater consideration.

Two reasons have led us to hypothesize a possible causal relationship between biases in attention and in expectancies. First, as stated earlier, these characteristic biases in fear and anxiety coexist. Second, recent neurophysiological evidence shows that visual cortical areas involved in orienting of attention—areas that are known to show enhanced activation when attention is allocated to a certain stimulus (e.g., Vuilleumier, 2005)—are also implicated in biased expectancies. For instance, Wik et al. (1996) found that reduced visual cortex activity in snake- or spider-phobic individuals was associated with increased encounter expectancies regarding the appearance of these animals in a neutral movie. The authors interpreted this reduced visual cortex activity as a sign of visual avoidance of the scene and thereby concluded it was a "neurophysiological correlate of avoidant anticipatory coping" (Wik et al., 1996, p. 267). Yet, because expectancies and brain activity were not directly related in this study, it remains unclear whether reduced visual cortex activity really is a specific correlate of phobogenic expectancies or of other components of the fear response.

To circumvent this problem, in another study, Aue et al. (2015) directly related brain activity to variations in on-line encounter expectancies. In line with the observations of Wik et al. (1996), we found reduced visual cortex activity to be characteristic of biased encounter expectancies for phobic threat. From the findings of these two studies, and the theoretical perspectives outlined at the outset of this section, we hypothesized common underlying mechanisms for biases in attention and biases in expectancies, as well as causal relations or mutual influences between the two.

Studies Investigating Associations Between Expectancy and Attention Biases

In two studies, we explicitly investigated the association of processes related to attention and expectancies in healthy and in phobic participants. The first study (Aue, Hoeppli, et al., 2013) revealed that eye gaze during controlled stimulus processing (as measured by eye tracking) strongly correlates with the encounter expectancy bias revealed by spider-phobic participants. The greater the visual avoidance the spider-phobic individuals exhibited when confronted with spider pictures, the lower they rated their chances of encountering spiders. Thus, less attention toward spiders in spider phobia is associated with particularly low encounter expectancies. The reverse link was observed in participants who were not fearful of spiders. This pattern of response suggests that visual avoidance of spiders among spider phobics may act to downregulate encounter expectancies, thereby decreasing subjective fear. Nonfearful controls, in contrast, may be able to better downregulate expectancies by paying particularly strong attention to them.[15]

Because the data in this study were purely correlational in nature, however, we cannot conclude which process (expectancy, attention, or a third unknown process) caused the effect. In addition, whereas this study concentrated on avoidance mechanisms in visual attention, we were also interested in how expectancies relate to early attentional engagement. In a second study (Aue, Guex, Chauvigné, & Okon-Singer, 2013), therefore, we investigated the causal influence of expectancies on early engagement of attention. Specifically, we postulated that prior expectancies about the occurrence of threatening events would exert a top-down influence on the visual search for threat (i.e., attention engagement in threat-related targets) by the activation of corresponding working memory contents.[16] Thus, we hypothesized the mechanism underlying expectancy influences on attention to consist of a mediating role of working memory processes (further considerations regarding memory-guided attention are presented in the following section), although memory content had not been explicitly registered in our study.

Encounter expectancies were experimentally manipulated by preinforming participants about the likelihood that a deviant animal in a visual search array of nine

[15] These group-specific associations between eye gaze behavior and encounter expectancies were not unique to spiders, but generalized to other animals investigated. Hence, there may be substantially different coping styles in phobic versus nonfearful individuals, coping styles that are not specific to the treatment of phobic content.

[16] Alternatively, or in addition, such a top-down influence could be a result of motivational influences, such that highly fearful individuals expecting to encounter their feared animal are more strongly motivated to overcome or avoid the situation and thus are particularly vigilant.

animals would be a spider or a bird. Attention bias was measured by assessing the time a participant needed to indicate whether the deviant animal was a spider or a bird. Notably, in disagreement with our hypotheses, the results of this study suggest that external manipulations of individual expectancies do not influence initial attention engagement regarding biologically threatening stimuli such as spiders. Phobic participants showed a pronounced and persistent attention bias toward spiders, irrespective of previously presented expectancy cues. Moreover, expectancy cues did not influence RTs for spider detections in low-fearful (i.e., healthy) controls.

By contrast, experimental manipulations of individual expectancies successfully modulated attention to nonthreatening stimuli (detection of birds), indicating that all participants paid attention to the expectancy cues and were able to profit from them in neutral situations (for further evidence of expectancy influences on attention engagement to neutral stimuli, see Burra & Kerzel, 2013). The expectancy-attention link that we observed for neutral targets, thus, conforms to models of visual detection (e.g., Duncan & Humphreys, 1989; Wolfe, 2003, 2010; for details, see previous section; see also considerations of Hutchinson & Turk-Browne, 2012, on memory-guided attention in the following section) that consider prior expectancies and working memory representations to be causal factors implicating visual search. Yet, these models cannot be applied to the spider stimuli included in our study.

There was no effect of prior expectancies for spider targets, either in spider phobics or in low-fearful controls. One may tend to explain this lack of effect in phobics by the fact that phobic individuals display generally increased expectancies of encountering (i.e., being presented with images of) spiders (e.g., Aue & Hoeppli, 2012;

de Jong & Muris, 2002). The experimentally induced expectancies may have been too weak to counteract such habitual encounter expectancies, and so they were possibly unable to have an impact on the typically observed vigilance behavior for spiders in spider phobics.

Our finding, however, that the RTs of low-fearful controls to spider targets also remained unaffected by the predicting cues is inconsistent with such an interpretation. This result cannot be explained by habitually increased encounter expectancies for spiders, because low-fearful individuals are usually characterized by a lack of an encounter expectancy bias. A more plausible interpretation of our findings, therefore, is related to biological preparedness theory. In line with this theory, our data may imply that evolution has led to the formation of attentional systems that are specific to the detection of phylogenetically salient stimuli such as spiders and are less penetrable to variations in expectancies than are systems used for the detection of nonthreatening stimuli. In contrast, as noted earlier, our data point to a relation between encounter expectancies and attention deployment in safe environments.

Together, the findings of these two studies support the idea of an association between biases in attention and expectancies for threat, in which visual attention possibly has an impact on individual expectancies and not vice versa. Yet, it is also conceivable that expectancies, while not influencing early attention engagement, do influence later, typically more controlled, attentional processes, such as visual avoidance. Clearly, more research is needed to draw firm conclusions about the directionality of influences. The role of memory processes and other cognitive factors as potential mediators also needs to be more directly addressed (see next section).[17]

The interrelation between attentional- and expectancy-related processes may not be specific to anxiety (disorders), but rather may extend to other types of psychopathologies. For example, depression is characterized both by attention biases to negative information (e.g., B. P. Bradley, Mogg, & Lee, 1997; Koster, De Raedt, Goeleven, Franck, & Crombez, 2005; Leyman, De Raedt, Schacht, & Koster, 2007) and by expectancy bias (Beck, 1976); recent models emphasize that negativity bias, defined as a predisposition towards hypersensitivity to stress and expecting negative outcomes, lies at the core of depression, influencing both feeling states and processing (Harmer et al., 2009; L. M. Williams et al., 2009). These considerations demonstrate that it might be worthwhile to link these alternative biases with expectancy and attention processes in fear and anxiety.

Extending the Focus to Underlying Mechanisms and Other Information-Processing Biases

From the studies reviewed earlier, we postulate a link between attention and expectancy bias, with attention bias causally influencing expectancies. While our data are suggestive, we need more research in order to determine causality and to gain better

[17] Of note, contrary to our own observations, research on pain in a healthy population (Boston & Sharpe, 2005) describes an influence of threat expectancy on attention deployment in a secondary task. Surprisingly, though, expectancy of sensory pain decreased rather than increased attention for words related to sensory pain.

insight into the concrete mechanisms underlying the presumed transfer of one bias into the other. One way toward this aim consists in the simultaneous consideration of other biases that have been observed in fear and anxiety (e.g., memory bias, interpretation bias), thus incorporating all stages of information processing.

Indeed, several studies to date suggest the importance of memory and interpretation particularities in attention and expectancy biases. Butler and Mathews (1983), for instance, suggested that the "detailed nature or vividness of an imaginal event may enhance its salience or accessibility in memory and, hence, increase the estimate of subjective risk" (p. 52). One way to increase the vividness of an event is by the attribution of attention. According to such a view, the influence of biases in attention on expectancies would be mediated by biases in memory.

Whereas such complex mediation effects have not yet been examined, recent research demonstrates links between attention and memory bias among patients with social anxiety disorder and comorbid major depressive disorder (LeMoult & Joormann, 2012). Furthermore, new findings propose that biased attention can cause memory biases for negative words among those socially anxious individuals who are characterized by comorbid depression (Blaut, Paulewicz, Szastok, Prochwicz, & Koster, 2013). In a similar vein, Vrijsen, van Oostrom, Isaac, Becker, and Speckens (2014) used principal components analysis to show coherence between attention and memory biases in formerly depressed individuals. Note, however, that there was no evidence for direct correlations between these biases (see also Gotlib, Krasnoperova, Yue, & Joormann, 2004, for lack of relations between these biases). Equally important is that, while informative, these studies do not allow inferences about whether and how exactly these cognitive biases affect each other, because different stimuli have been used in the tasks targeting attention and memory bias.

It is also conceivable that memory exerts a causal influence on attentional processes, an idea that is expressed in the term memory-guided attention (e.g., Hutchinson & Turk-Browne, 2012; see Everaert, Fan, Koster, and Turke-Browne, 2014, for evidence of memory-guided attention in depression). The potential mechanisms by which memory content can influence attention deployment are manifold and refer to different memory systems. Hutchinson and Turk-Browne (2012) describe empirical evidence regarding memory-guided attention as being related to priming and associative learning, as well as working, episodic, or semantic memory. Without doubt, prior experience with a situation that has formed memory traces helps to direct attention toward relevant features in future situations that are alike. The role of expectancies in this translation is still to be determined.

Although we did not find evidence for a causal influence of expectancies on attention to external threat (Aue, Guex, et al., 2013), expectancies may still be hypothesized to guide attention toward threatening internal information, such as internally generated cues related to past experience or interpretations. According to such a view, attention could function as a mediator of expectancy influences on memory access. On the other hand, it is also conceivable that memory serves as a source from which concrete expectancies are derived. That expectancy and memory processes may be related in fear and anxiety receives support from the observation of reduced positivity biases in memories and expectancies about the future in individuals who score high on the trait of worry compared with those who score low (Finnbogadóttir & Berntsen, 2013).

These complex thoughts demonstrate that bidirectional and mediating or moderating influences between fear-related biases in expectancies, attention, and memory are well imaginable.

Furthermore, interpretation bias (e.g., Grey & Mathews, 2000; Mathews & Mackintosh, 2000; see also overview in Mathews & MacLeod, 2002) may be a precedent or a consequence of biases in attention, expectancies, and memory. It may also function as a mediator of the association among the other biases. Becker and Rinck (2004), for example, investigated whether fearfulness is really associated with greater sensitivity to harmful material, as suggested by the results of research on attention bias (see Frenkel, Lamy, Algom, & Bar-Haim, 2009, for highly similar research on emotional facial expressions and anxiety), or whether fearful and nonfearful individuals use different decision strategies related to differential interpretations of the same situation. In their investigation, the participants' task was to decide whether pictures did or did not display spiders, beetles, and butterflies. The results of a signal detection analysis revealed comparable sensitivity to spiders among spider fearful and spider nonfearful participants. Yet, spider fearful individuals were characterized by a more liberal response criterion for spiders than were the nonfearful individuals, thus biasing their interpretation of the situation.[18] This pattern of responses also held for beetles but not flowers, demonstrating only limited specificity of the described link between fearfulness and response criterion threshold.

[18] The study by Frenkel et al. (2009) showed, in addition, that anxious individuals are characterized by more conservative response criteria for happy facial expressions than are nonanxious controls.

These observations suggest that the reported effects on attention bias may be partly a result of interpretation differences between high- and low-fearful individuals. High fear and anxiety may correspond with a lower degree of tolerance for ambiguity or uncertainty (cf. Buhr & Dugas, 2006, Holaway, Heimberg, & Coles, 2006, and meta-analytic data in Gentes & Ruscio, 2011, for a relation between intolerance for uncertainty and worry in different anxiety disorders; see Grenier, Barrette, & Landouceur, 2005, for similarities and differences between intolerance to uncertainty and intolerance to ambiguity). Thus, when anxious, fearful, and phobic individuals are in doubt, they may choose the threat interpretation in order to be prepared for the worst case, which is consistent with evidence for biased negative interpretation of ambiguous cues in fear and anxiety (e.g., MacLeod & Cohen, 1993). Indeed, it has been previously suggested that threat processing among fearful or anxious individuals is often rigid (automatic thoughts; see Beck et al., 1985) and dichotomous, with concurrent intolerance for uncertainty or ambiguity.[19] Moreover, there is indication that anxiety-related interpretation bias may causally influence memory bias (e.g., Eysenck, Mogg, May, Richards, & Mathews, 1991).

Furthermore, Hertel, Brozovich, Joormann, and Gotlib (2008) showed intimate links between interpretation and memory biases in generalized social phobia (see also Lundh & Ost, 1997), and Amir, Bomyea, and Beard (2010) reported that training socially

[19] An alternative way to interpret the results of Becker and Rinck (2004) is that highly fearful individuals are preoccupied with their feared objects and are therefore particularly prone to develop illusory correlations between certain stimulus classes (e.g., spiders) and aversive outcomes. These correlations then should be of direct relevance for biases in consequence expectancies.

anxious individuals with an interpretation modification program resulted in facilitated ability to disengage attention from threat. Even situational interpretations of unselected populations can be experimentally manipulated into the negative or positive direction by adequate training procedures, thus producing a corresponding bias in memory (Tran, Hertel, & Joormann, 2011).

From the findings described in this section and observations that biases in attention, expectancy, memory, and interpretation coexist in anxiety disorders, we suggest that the mutual impacts of the different biases reinforce each other to form a vicious circle, thereby enhancing fear and anxiety behaviors (see Mathews & MacLeod, 2002, for an overview of studies displaying a causal influence of attention and interpretation biases on emotional vulnerability [i.e., anxious symptoms]). Nevertheless, the exact pattern of causality has yet to be explored and should be the focus of future studies. The difference between pathological forms of fear and normal fear may lie in the fact that healthy individuals are able to break through this vicious circle at some point and/or adaptively regulate their fear. Alternatively, attention bias and expectancy bias may be linked in opposite directions (positive vs. negative association; see Aue, Hoeppli, et al., 2013, for supportive evidence) in these different populations. That expectancies may have an impact on attention differently in highly anxious and phobics versus controls would be in line with Mills, Grant, Judah, and White's (2014) observation of a differential association of apprehensive anticipatory processing (in the form of repetitive negative thinking) and attention bias in high versus low socially anxious individuals.

Some Future Directions

Future envisaged developments constitute an additional distinction between the different subtypes of the biases considered here (e.g., attention bias: early attention engagement, early attention disengagement, later attentional avoidance; expectancy bias: consequences, encounter; memory bias: encoding, consolidation, retrieval). As we outlined in the previous section, early attention biases in anxiety and phobia (e.g., facilitated initial engagement in threat) may conceivably have a causal impact on encounter and consequence expectancies. Yet, these expectancies may then have repercussive effects on subsequent attentional engagement. Biased expectancies may, for instance, provoke visual avoidance in order to downregulate subjective feelings of fear.

Future investigations in the area may therefore be inspired by work on the combined cognitive biases hypotheses regarding depressed populations (Everaert, Duyck, & Koster, 2014). The author’s path analyses revealed (a) an influence of early selective orienting on interpretation bias, which itself was related to a memory bias, but also (b) an effect of maintenance of attention and interpretation on memory bias (see also Everaert, Tierens, Uzieblo, & Koster, 2013). These works highlight the importance of distinguishing between different attentional mechanisms (e.g., selection mechanism, as assessed here by frequency of fixation, and maintenance mechanism, measured here by duration of fixations).

In general, questions addressing the link between different processing biases can be classified into three different categories: association, causal, and predictive magnitude (see Everaert, Koster, & Derakshan, 2012, for details). Some pioneering work now exists for the first two categories in research on attention-expectancy relations: An association between attention and expectancy biases has been demonstrated in fear of spiders, with attention biases possibly causally influencing expectancies but not vice versa. It remains an open question, however, as to whether the simultaneous consideration of different biases increases predictive power regarding fear intensity. Furthermore, yet to be examined is whether effects corresponding to the different biases act simultaneously or in succession and whether they act additively or multiplicatively. Such investigations of different vulnerability factors (i.e., different information-processing biases) and the comprehension of their interplay may substantially advance our understanding of the origins and the maintenance of anxiety disorders.

Finally, recent evidence highlights the role of motivation in processing biases. Vogt, De Houwer, and Crombez (2011) used a dot-probe task to demonstrate attention deployment to the location of cues associated with high value or high expectancy of success, compared with stimuli associated with low value or low expectancy of success. Even when contrasted with threat cues, attention was allocated to stimuli that were goal-relevant (Vogt, De Houwer, Crombez, & Van Damme, 2013). Such effects were not limited to healthy individuals, but were found in anxious participants as well. Together, these findings highlight the effect of individual goals and associated (positive) expectancies on attention bias. In the future, motivational factors should therefore be considered as well.

Conclusions and Outlook

The evidence summarized in this article points to robust attention and expectancy biases among anxious, fearful, and phobic individuals. Recent studies point to an association between these biases, emphasizing the need for future examination of their shared neurocognitive mechanisms. Such research efforts are crucial for a better understanding of processing biases in threatening situations and may have important theoretical and clinical implications. In future research, terminology—especially with respect to biased expectancies—should be unified to facilitate comparability of the results of different studies examining the causality of influences among different processing biases. Earlier findings (see, for instance, Mathews & MacLeod, 2002) demonstrated that at least attention and interpretation biases are somewhat malleable and can be changed quite easily in the desired direction via CBM procedures. The application of these procedures turns out to be an important and interesting venue for a test of an association between different processing biases because it allows for inferences regarding causality. Corresponding procedures for expectancy bias remain to be developed. Demonstration of a mutual influence among the different biases considered here could therefore lead to a breakthrough in the development of adequate and efficient treatments of anxiety disorders.

In particular, future research should focus on the following issues: First, whether there actually are reliable associations between diverse types of information-processing biases in normal and pathological fear needs to be examined. If these links do indeed exist, a number of additional questions have to be addressed. Most important, causality has to be determined. Furthermore, the degree of specificity versus generalizability across different forms of fear/anxiety and different contexts of these links needs to be investigated. Moreover, the exact cognitive and biological (e.g., at the neural but also at the peripheral level) mechanisms at the basis of such links should be identified. The application of more sophisticated statistical models (e.g., Everaert, Duyck, & Koster, 2014) could pay off here. Ideally, these investigations will also uncover simultaneous or successive, as well as additive or multiplicative, effects of the different biases on experienced fear.

From a clinical perspective, understanding the causal mechanisms at the basis of anxiety is crucial in order to develop effective therapeutic approaches. The identification of causal cognitive processes will enable therapists to address pathological fear and anxiety at its roots, which promises better treatment outcomes. Similar efforts have been conducted in the context of depression: For instance, self-reported negativity bias was related to more accurate detection of negative facial expressions (disgust and sadness), as well as to a greater tendency to interpret neutral facial expressions as angry (Watters & Williams, 2011). In addition, other works (Di Simplicio et al., 2014; Harmer et al., 2009) demonstrate that the common pharmacological treatments to depression, serotonin-specific reuptake inhibitors (SSRIs), modulate attention biases and change the balance from maladaptive enhanced orienting of attention to negative information to a more balanced orienting toward positive stimuli. This change is suggested to be mediated via prefrontal-limbic neural pathways, in line with numerous imaging studies showing that these pathways are associated with emotional processing and regulation (for reviews, see Iordan et al., 2013; Okon-Singer et al., 2015). Similar investigations in fear and anxiety have the potential to reveal the neural basis for maladaptive causal cognitive mechanisms, as suggested here. Follow-up clinical works may modulate these neural systems via cognitive training or neuro-focused techniques such as neurofeedback or transcranial magnetic stimulation (TMS).

Finally, neurophysiological evidence indicates that attention and expectancies closely interact in the appearance of positive cognitive biases such as optimism bias (also called wishful thinking; Aue, Nusbaum, & Cacioppo, 2012). The degree of wishful thinking displayed by healthy participants varies as a positive function of the functional connectivity between the visual cortex and the human reward system. Because wishful thinking is actually a positive expectancy bias (defined as the tendency to overestimate the likelihood of positive future outcomes), the data support the notion that attention biases toward positive evidence—possibly driven by the human reward system—generate positive expectancy biases or vice versa. Therefore, it is necessary to examine whether the links between attention and expectancy biases observed in the negative affect domain are valence-specific, or whether they are more general in nature and extend to the positive affect domain.

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Figure Captions

Figure 1. Typical expectancy bias paradigms in research on fear of spiders. (A) Differentiation between *consequences* expectancy bias and *encounter* expectancy bias. (B) Differentiation between *off-line* and *on-line* expectancy biases, as demonstrated along a time scale.

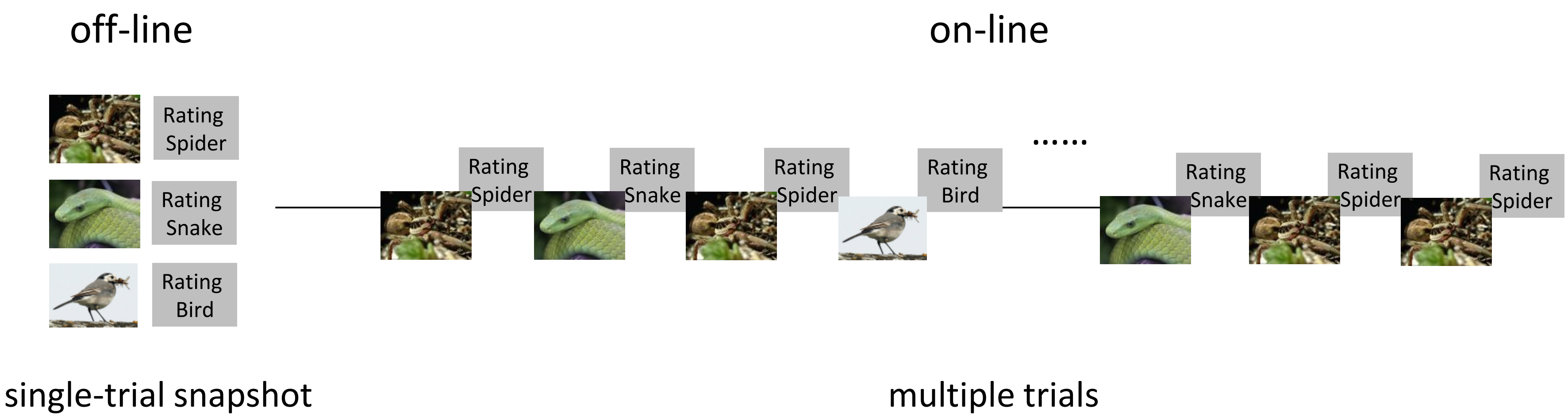
Figure 2. Typical paradigms used to examine attention bias in the literature. Note that specific factors related to timing, order, and type of stimuli vary between studies. (A) On the *emotional Stroop* task, participants are asked to ignore the meaning of the word and respond according to the ink color. (B) On the *dot-probe task*, participants are required to report a target (here, for example, the orientation of two dots) that appears in a location previously occupied by an emotional or a neutral picture. (C) In the emotional modification of the *spatial cuing paradigm*, a target appears in a location previously cued by a neutral or an emotional item. (D) In emotional variations of the *visual search task*, participants search for an emotional target embedded among neutral distractors. Alternatively, a neutral target may be embedded among emotional distractors. Attention biases are typically assessed by comparing reaction time and accuracy between emotional and neutral conditions. Stimulus images courtesy of Michael J. Tarr, Center for the Neural Basis of Cognition and Department of Psychology, Carnegie Mellon University, http://www.tarrlab.org/ and http://www.shutterstock.com/

A

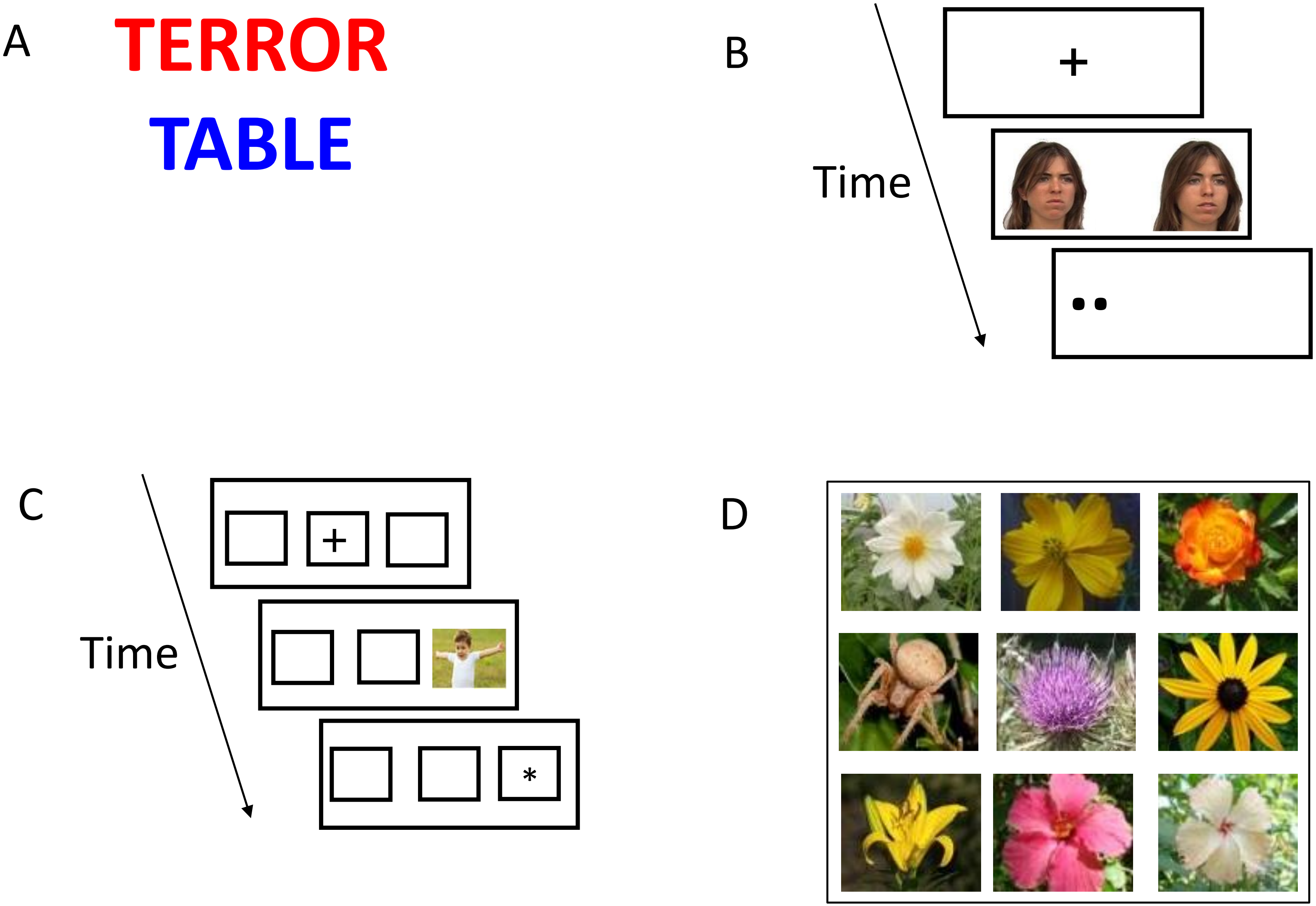
Consequences expectancy bias: “What is the likelihood that the animal displayed will harm you/the presentation of the picture of the animal displayed will be followed by an electric shock?”

Encounter expectancy bias: “ What is the likelihood that you will encounter the animal/that an image of the animal will be displayed?”

B



(in conditioning-type experiments [e.g., consequences expectancy bias regarding the application of electric shocks]: same number of negative outcomes for all stimulus categories)


A
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