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# Attentional Bias for Positive Emotional Stimuli: A Meta-Analytic Investigation

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Despite an initial focus on negative threatening stimuli, researchers have more recently expanded the investigation of attentional biases toward positive rewarding stimuli. The present meta-analysis systematically compared attentional bias for positive compared with neutral visual stimuli across 243 studies ( $N = 9,120$  healthy participants) that used different types of attentional paradigms and positive stimuli. Factors were tested that, as postulated by several attentional models derived from theories of emotion, might modulate this bias. Overall, results showed a significant, albeit modest (Hedges'  $g = .258$ ), attentional bias for positive as compared with neutral stimuli. Moderator analyses revealed that the magnitude of this attentional bias varied as a function of arousal and that this bias was significantly larger when the emotional stimulus was relevant to specific concerns (e.g., hunger) of the participants compared with other positive stimuli that were less relevant to the participants' concerns. Moreover, the moderator analyses showed that attentional bias for positive stimuli was larger in paradigms that measure early, rather than late, attentional processing, suggesting that attentional bias for positive stimuli occurs rapidly and involuntarily. Implications for theories of emotion and attention are discussed.

*Keywords:* attentional bias, positive emotion, reward, emotional theories, attention

Emotions guide behavior (e.g., approach or avoidance), modulate many cognitive processes (e.g., memory and decision making), and signal the presence of important events in the environment (Sander, Grandjean, & Scherer, 2005). When several stimuli compete for access to the limited attentional resources of an individual, a bias toward emotional stimuli allows efficient detection of these events and rapid preparation of adaptive reactions (Pourtois, Schettino, & Vuilleumier, 2013). Attentional bias for emotional stimuli has attracted considerable interest in neuroscience (Vuilleumier, 2005) and psychology (Van Bockstaele et al., 2014; Yiend, 2010). Initially, experimental research in both fields mainly focused on the negative

emotion of fear. Indeed, fear was one of the first emotions investigated in an experimental setting in neuroscience through fear conditioning in rodents (see LeDoux, 1996). The earliest investigations in human research tried to extend these findings with the use of fear-relevant stimuli such as faces expressing fear or anger (Mogg & Bradley, 1998; Vuilleumier, Armony, Driver, & Dolan, 2001). In addition, a large corpus of studies investigated attentional bias for threatening stimuli in healthy participants, as well as in participants experiencing a variety of anxiety disorders (for an encompassing meta-analysis on anxious and nonanxious participants, see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007).

Despite this initial focus on threatening stimuli, researchers have more recently expanded the investigation of attentional biases to rewarding stimuli. In the last decade, the topic of attentional bias for these positive stimuli has seen a large increase in interest. Several empirical experiments investigated attentional bias for positive stimuli in healthy individuals (Anderson, Laurent, & Yantis, 2012; Sali, Anderson, & Yantis, 2014) and in individuals experiencing substance addiction or eating disorders (Brignell, Griffiths, Bradley, & Mogg, 2009). Narrative reviews (Field & Cox, 2008; Franken, 2003) and a meta-analysis (Field, Munafò, & Franken, 2009) focused on attentional bias for positive stimuli in the context of substance abuse. However, fewer works have reviewed experiments conducted on healthy individuals. Recently, Anderson (2013) and Pessoa (2014) reviewed experiments on attentional bias toward positively valued stimuli in healthy participants, but to the best of our knowledge, no quantitative review has been conducted. Therefore, the goal of the present meta-analysis was to (a) systematically compare attentional bias for positive stimuli found across different experiments and (b) test whether the emotional properties of a stimulus, which are conceived as

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fundamental in major theoretical models of emotion, modulate this bias.

### Attentional Bias for Emotional Stimuli and Theories of Attention

One of the major challenges for cognitive sciences is to understand how organisms deal with their limited resources in a multifarious and rapidly changing world (Posner, 1980). Not all of the information entering the sensorial system can be processed and represented thoroughly (Marois & Ivanoff, 2005). How do organisms manage this overload of information? This function is typically imputed to attention, which selects the subset of stimuli that can access the organisms' limited resources to be more thoroughly represented (Desimone & Duncan, 1995; Posner & Petersen, 1990).

A large variety of processes influence attentional selection (Pourtois et al., 2013), but classically, two sources of influence are distinguished (Corbetta & Shulman, 2002; Posner, Snyder, & Davidson, 1980; Shiffrin & Schneider, 1977). The first influence is driven by the low-level perceptual characteristics of the stimulus and is often referred to as *exogenous attention*. When a stimulus has some particularly salient physical properties (e.g., color, size, or an unexpected and sudden onset), attention is rapidly and involuntarily oriented toward it, even if this stimulus is not relevant to the current task that the individual is performing (Theeuwes, 1994). The second influence is driven by the goals and strategies of the individual and is referred to as *endogenous attention*. This process is voluntary, consciously initiated, and less rapid than exogenous attention: Attention is oriented toward the stimuli related to the task that the individual is currently trying to achieve (Folk, Remington, & Johnston, 1992). Even though these two influences are functionally different, they are not mutually exclusive or fully independent (Egeth & Yantis, 1997). While they rely on partially segregated brain networks (i.e., frontal and parietal cortex, as well as some subcortical structures), they generally function in a similar manner: These networks amplify the activity of the sensorial regions that process the representation of the salient or task-relevant stimulus to the detriment of other competing stimuli (Corbetta & Shulman, 2002).

It has been proposed that a stimulus' emotional content might represent a third distinct source of influence on attentional selection (Brosch, Pourtois, Sander, & Vuilleumier, 2011; Compton, 2003; Holland & Gallagher, 1999; Lang, 1995; Pourtois et al., 2013; Vuilleumier, 2005). A consistent corpus of experiments showed that when several stimuli compete for the organism's resources, attention is biased toward emotional stimuli (Yiend, 2010). This affective-driven modulation is referred to as *emotional attention* (Vuilleumier, 2005) or *motivated attention* (Lang, 1995). Like exogenous attention, emotional attention is rapid and involuntary; it is also comparable to endogenous attention, however, as it strongly depends on some of the observer's internal factors, such as the affective state (e.g., a state of anxiety; Bar-Haim et al., 2007). Some investigators have proposed that exogenous attention, endogenous attention, and emotional attention have an additive influence on attentional selection (Brosch et al., 2011), thereby suggesting that these three systems can operate simultaneously and that they each have a unique influence on attention (Pourtois et al., 2013). Moreover, emotional attention has been shown to be par-

ticularly mediated by a neuronal structure (i.e., the amygdala) that differs from the structures that mediate exogenous and endogenous attention (Vuilleumier, 2005; Vuilleumier & Brosch, 2009). Even though a distinct neuronal network seems to mediate emotional attention, it has the same effect on the brain areas that process sensorial information: It boosts the neuronal representation of the emotional stimulus, making it more robust and, therefore, more likely to win the competition for processing resources and gaining access to awareness (Pessoa, Kastner, & Ungerleider, 2002). There is a general agreement on the amygdala's activity enhancing the sensory analysis of the emotional stimuli. However, the degree of automaticity of this perceptual enhancement underlying attentional biases remains debated. Some authors claim that emotional stimuli are processed automatically and independently of voluntary attentional processes (Brosch et al., 2011; Pourtois et al., 2013; Vuilleumier, 2015), because emotional stimuli are processed even when voluntary resources are allocated elsewhere. Other authors claim that attention toward emotional stimuli requires the participation of voluntary resources (Lavie, 2005; Pessoa, Kastner et al., 2002; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002), considering that a high voluntary attention load seems to abolish the processing of emotional distractors. The time-course of the emotional attention effects might provide important insights to this debate. Early attentional mechanisms, such as initial orienting, that appear rapidly (i.e., before 120 ms after the stimulus onset) are conceived as independent of the observer's intentions. Later attentional mechanisms, such as difficulty in disengaging one's attention, that appear more slowly (i.e., 200–250 ms after the stimulus onset), are more likely to be influenced by voluntary processes (Theeuwes, 2010; Theeuwes & Belopolsky, 2012). Therefore, if emotional attention effects are automatic and independent of voluntary processes, they should already modulate early attentional mechanisms; whereas if emotional attention effects require voluntary processes they should only influence later attentional mechanisms. Accordingly, investigations using electroencephalic measures provided evidence corroborating the automaticity hypothesis, by showing that the perceptual enhancement of emotional stimuli appears at very early stages of visual processing. Strikingly, emotional stimuli seem to modulate Event Related Potential (ERP) components appearing at very early stages of visual processing (i.e., before 150 ms) such as the C1 component generated by the visual perceptual areas (Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Stolarova, Keil, & Moratti, 2006). In the present meta-analysis, we investigated this question by coding several moderators reflecting early versus later attentional mechanisms.

### Moderators Characterizing Attentional Bias

#### Attentional Bias Subcomponents

Attentional biases can be driven by two mechanisms: (a) *initial orienting* toward the stimulus, or (b) *difficulty in disengaging* attention from the stimulus and reallocating it toward another stimulus (Posner, Inhoff, Friedrich, & Cohen, 1987). Although this differentiation has been recognized as important (Field et al., 2009), measures of attentional bias do not always allow distinction between these two subcomponents. The initial orienting is conceived as an early preselective mechanism driven by the stimulus, independently of the intentions of the observer (Theeuwes, 2010;

Theeuwes & Belopolsky, 2012). Initial orienting influences the first attentional shift, which occurs before 150 ms. The difficulty in disengaging one's attention occurs after the first attentional shift and after the stimulus has been selected; therefore, compared with initial orienting, it is a later mechanism that occurs after 200–250 ms (Weierich, Treat, & Hollingworth, 2008). These two subcomponents of attentional biases are dissociable processes that can be differentially manipulated (Born, Kerzel, & Theeuwes, 2011). Recent studies (Pool, Brosch, Delplanque, & Sander, 2014; Theeuwes & Belopolsky, 2012) parsing the contribution of these two subcomponents in attentional bias for positive stimuli suggested that the bias is driven by an initial orienting more than a difficulty in disengaging attention. In the present meta-analysis, a moderator was coded on the subcomponent of attentional bias (*initial orienting* or *difficulty in disengagement*) when the experimental paradigm used in the study allowed such a distinction.

### Experimental Paradigm

To study the influence of emotion on attentional selection, several experimental paradigms have been created on the basis of classical cognitive tasks. The *dot probe detection task* is probably the most used paradigm in the study of attentional bias for emotional stimuli (Yiend, 2010). Participants are asked to detect as fast and precisely as possible the location, orientation, or identity of a target that appears in the same place as one of the two cues that were presented simultaneously before the target. One of these two cues has an emotional value, whereas the other is neutral. When attention is oriented toward the emotional cue, participants are faster at detecting the target when it appears in the location previously occupied by the emotional cue compared with when it appears in the location previously occupied by the neutral cue. Although it is well recognized that this index reflects a bias in attentional orienting, on the basis of the behavioral performances, it is impossible to disentangle whether the bias is because of initial orienting toward the emotional cue or difficulty in disengaging attention from the emotional cue and reorienting it toward the target (Fox, Russo, & Dutton, 2002; Posner, 1980). However, in some adaptations of the dot probe detection task (Koster, Crombez, Verschuere, & De Houwer, 2004), such a distinction becomes possible thanks to the addition of a condition with two neutral cues furnishing a neutral baseline. Comparison of such a baseline with trials in which the target appears at the same location as the emotional cue reflects initial orienting, whereas comparison of the baseline with trials in which the target appears at the location opposite to the emotional cue reflects difficulty in disengagement.

The *spatial cuing task* has been specifically designed to simultaneously measure initial orienting and difficulty in disengagement through a simple behavioral index (Posner & Cohen, 1984). In this task, a single cue is briefly presented before a target. The cue can be emotional or neutral, and participants are asked to detect the target. In valid trials, the target appears in the same location as the cue; faster reaction times (RTs) in trials with an emotional cue compared with a neutral cue are taken to reflect initial orienting toward the emotional cue. In invalid trials, the target appears in the opposite location to the cue; slower RTs to detect the target after the emotional cue compared with the neutral cue are taken to reflect difficulty in disengaging attention from the emotional cue.

A simple *free viewing task* is often used with a direct measure of attention such as eye movements. Classically, an emotional and a neutral image are presented simultaneously and the measures of the first saccade (e.g., probability of fixating, velocity) represent initial orienting, whereas the later measures (e.g., dwelling time, proportion of fixation) represent difficulty in disengagement.

In *visual search tasks*, participants are asked to search for a specific target among several distractors. Participants are faster at detecting an emotional stimulus among neutral distractors and slower at detecting a neutral target among emotional distractors compared with when they have to detect a neutral stimulus among neutral distractors. This task reflects attentional bias in the most ecological way. However, as in the classical versions of the dot probe detection task, it is impossible to disentangle initial orienting from difficulty in disengagement.

Whereas the aforementioned tasks are used to investigate the spatial dimension of attention, the *rapid serial visual presentation (RSVP) task* targets its temporal dimension. A series of images rapidly appears one after the other, with each image displayed briefly (about 100 ms). Participants are asked to attend to a particular type of target in this stream. A single target can be reported accurately, but reporting a second target is considerably impaired when the two targets are presented within a short interval (200–500 ms). This impairment, termed attentional blink, reflects attentional capacity limitations that restrict access to awareness (Shapiro, Raymond, & Arnell, 1997). Attentional blink has been shown to be considerably attenuated when the first target is neutral and the second target is an emotional stimulus; similarly, attentional blink is considerably increased when the first target is emotional and the second is neutral (Anderson, 2005). Modulation of the attentional blink may be underlined by early and rapid attentional processes that can be assimilated to initial orienting (Field et al., 2009); because no concrete empirical evidence has demonstrated this, however, in the present meta-analysis, we considered this task to reflect global attentional bias.

In other tasks, emotional cues and neutral task-relevant targets are not divided by spatial or temporal factors and are presented simultaneously on the same stimulus. This is the case of the emotional *Stroop task* in which participants are presented with emotional words or photos in different colors and asked to name the color of the ink as fast as possible and to ignore the semantic/emotional content of the stimulus. The attentional bias is indexed by the participant's RT in naming the color when the stimulus has emotional content compared with when it has neutral content. An "emotional Stroop effect" is reported when the emotional content involuntarily interferes with the task by slowing the participants' performances. Because it is easy to administer, this paradigm has been widely used in the literature, showing a robust emotional bias (Phaf & Kan, 2007, for a meta-analysis). Initially, the interference effect of emotion was attributed to early and rapid mechanisms (for a review, see Cox, Fardard, & Pothos, 2006); however, recent evidence suggests that this effect instead reflects a later process attributable to difficulty in disengaging attention (Field et al., 2009; Phaf & Kan, 2007).

Because these paradigms might reflect different aspects of attentional selection, we coded the moderators to assess how the use of a particular experimental paradigm influences the size of the attentional bias for positive stimuli.



## Measure and Stimulus Target Asynchrony

In the present meta-analysis, studies using different types of measures of attentional biases are included. These measures are divided into two main categories: (a) measures of electroencephalographic activity and of eye movements are considered *direct*, and (b) behavioral performances reflecting the influence of attentional processes are considered *indirect* (Field et al., 2009). In indirect measures (i.e., RTs, accuracy), the influence of an emotional cue is assessed by detection of a subsequent neutral target. Therefore, the timing of the attentional bias crucially depends on the cue-target onset asynchrony (CTOA) of the emotional stimulus, whereas the timing of the bias can be measured independently of the exposure time of the emotional stimulus for direct measures. When the target appears immediately after the emotional cue (i.e., not more than 150 ms), the behavioral performance reflects the influence of the first attentional shift, which takes about 100–150 ms. A CTOA longer than 250 ms allows the participant to shift attention repeatedly; therefore, performances during target detection are more likely to reflect the fact that attention is held on the emotional stimulus and cannot be disengaged from it (Weierich et al., 2008). Because several paradigms using indirect measures do not allow disentanglement of initial orienting and difficulty in disengagement (e.g., classic version of the dot probe detection task), we coded time exposure of the emotional stimulus as a moderator for studies using indirect measures. This moderator provides a supplementary, although only indirect, indicator of the role of initial orienting and difficulty in disengagement in attentional biases for positive stimuli.

## Attentional Bias for Positive Stimuli and Theories of Emotion

Despite the amount of evidence demonstrating that attentional selection is influenced by emotional stimuli, there is little agreement on the psychological mechanism underlying the influence of emotional stimuli on attention (Brosch, Pourtois, & Sander, 2010). More particularly, little is known about the properties allowing emotional stimuli to have such a privileged attentional status: If attention is biased toward emotional stimuli, it is fundamental to identify which properties qualify a stimulus as emotional.

The three major theories of emotion (basic emotion, circumplex, and appraisal theories) have focused on different mechanisms defining a stimulus as emotional, and three different models of emotional attention (Anderson, 2005; Brosch, Sander, Pourtois, & Scherer, 2008; Öhman & Mineka, 2001) have been derived from them. Although the prediction for negative threatening stimuli is similar across the three different models of emotional attention, different predictions exist concerning positive rewarding stimuli.

Positive rewarding stimuli have been defined as stimuli having a positive hedonic value, which elicit approach behaviors, produce learning of the behavior that led to the positive rewarding stimulus and engaged positive emotions (Berridge & Kringelbach, 2008; Schultz, 2004). These stimuli can be conceptualized as being symmetrically opposite to negative threatening stimuli in terms of valence and action tendency: Whereas the latter have a negative value and elicit avoidance, the former have a positive value and elicit approach. Positive rewarding and negative threatening stimuli, being both affectively relevant, share several brain structures

in their processing such as the amygdala and the orbitofrontal cortex (e.g., Li, Howard, Parrish, & Gottfried, 2008; Murray, 2007; Sander, Grafman, & Zalla, 2003). Traditionally, however, other structures such as the dopaminergic midbrain structures and the ventral striatum, have been selectively linked to positive reward processing (Berridge & Robinson, 1998; Schultz, 2004).

Basic emotion theory proposes that discrete basic emotions (e.g., fear, happiness) are each underlain by unique psychological mechanisms and neuronal signatures (Ekman, 1992). Therefore, according to this principle negative threatening stimuli and positive rewarding stimuli, reflecting different basic emotions (e.g., fear and happiness), should rely on different mechanisms and potentially have a different effect on attention. One attentional model, consistent with the basic emotion theory is that attention is rapidly directed toward emotional stimuli that represent a threat to the organism's survival (Flykt, 2006; Öhman & Mineka, 2001). According to this proposition, through evolution, organisms have developed an innate and automatic system implemented in the amygdala that biases attentional resources toward stimuli that have intrinsic perceptual features characteristic of classical threats to the species for which organisms have been *biologically prepared* (e.g., a snake shape). The emotional influence on attentional selection is conceptualized as being specific to threat; therefore, according to this model, positive stimuli should not bias attentional resources. Indeed, in interpreting the effect of positive and negative emotional stimuli on attentional selection, Öhman, Lundqvist, and Esteves (2001) wrote that there is "a constant affective activation effect exclusively pertaining to the threatening face. . . . Fear-irrelevant stimuli, on the other hand, only passed through the feature analyses . . ." (p. 393).

Circumplex theories of emotion propose a different underlying mechanism. They contest the assumption that single emotions (i.e., fear, anger, and happiness) function independently of each other and postulate that all emotions are underlain by two orthogonal dimensions: *valence*, which defines how positive and how negative one feels about the stimulus; and *arousal*, which defines the extent to which the stimulus triggers a sympathetic physiological reaction that is felt by the observer (Russell, 1980; Yik, Russell, & Barrett, 1999). From this assumption, it has been proposed that emotional stimuli influence attentional selection contingent on their potential to elicit emotional arousal, independently of their valence (Anderson, 2005). According to this model, the amygdala is the key structure orchestrating the arousal-modulatory influence on attention: Involved in both high arousing positive and negative stimuli (Anderson et al., 2003), the amygdala modulates the enhanced perceptual processing underlying the attentional bias (Anderson & Phelps, 2001). Therefore, according to this model, positive stimuli modulate attention only if they are high on the arousal dimension.

Appraisal theories of emotion (Moors et al., 2013; Moors, 2009; Scherer, Schorr, & Johnstone, 2001) also postulate that common mechanisms underlie the large variety of emotions. However, unlike the other theories, appraisal theories propose that the determining factor is the appraised relevance of the stimulus with respect to the organism's current concerns (Frijda, 1988; Sander, Grandjean, & Scherer, 2005). Current concerns are associated to affective responses and differ from purely cognitive task-relevant goals. Task-relevant goals do not

require commitment: they relate to the task instructions and begin and end in task context (Klinger, 1975). For instance, in a task in which the blue distractor has to be found, the blue color is task-relevant, but once the task is finished, it is no longer relevant. Current concerns relate to affective representations of psychological and physiological motives (e.g., self-achievement), needs (e.g., hunger), and values (e.g., security) that are of major importance for the individual (Frijda, 1988). They imply a state of commitment about their achievement that generalizes to different contexts and situations beyond a particular task (Klinger, 1975). For instance, in a task in which our own name has to be found, our own name is task relevant as well as relevant for the current concern of self-identity; its relevance does not end with the task. A multitude of concerns can be identified as belonging to one of two categories in a theoretical classification proposed by Frijda (2009): source concerns are shared across individuals, are relatively stable, and are commonly recognized (e.g., offspring caregiving, affiliation, and self-affirmation) and surface concerns are specific to an individual at any given time and situation (e.g., being hungry, being attracted to a specific person; Frijda, 2009). Source and surface concerns are not conceptualized as opposite categories, a given stimulus can be relevant to both surface and source concerns simultaneously (e.g., a food stimulus can be relevant to the common concern of nourishment and the specific concern of hunger; Rodriguez Mosquera, Fisher, & Manstead, 2004). According to appraisal theories, organisms developed a system to rapidly detect stimuli that are relevant to their current concerns: If a stimulus is appraised as being affectively relevant, it has privileged access to the individual's resources. From this assumption, it has been proposed that the influence of emotional stimuli on attentional selection critically depends on the stimulus' relevance for the observer's concerns: The amygdala rapidly detects the stimulus' relevance and enhances the cortical perceptual representation of the relevant stimulus that becomes more salient and likely to bias attention (Brosch et al., 2008; Brosch, Sander, & Scherer, 2007; Brosch, Scherer, Grandjean, & Sander, 2013; Sander et al., 2003). Similarly to the attentional model derived from circumplex theories, this proposition also postulates that positive stimuli have facilitated access to attention, independently of their intrinsic properties. For instance, a particular positive stimulus (e.g., an erotic image of a woman) can be relevant and elicit a physiological state of arousal for one individual (e.g., a heterosexual man), but not for another (e.g., a heterosexual woman). However, there is a fundamental difference between the two models. According to models derived from appraisal theories, the attentional bias is driven by an early and automatic relevance appraisal that occurs before the emotional response, whereas models derived from circumplex theories postulate that the bias is driven by a relatively later mechanism consisting of the felt physiological response of arousal.

In the present meta-analysis, we investigated this question by coding several moderators reflecting the fundamental emotional properties of positive stimuli according to the aforementioned theories. We took advantage of the large existing literature that has tested attentional biases using a large variety of stimuli with different levels of valence, arousal, and relevance to investigate the predictions of the models of emotional attention derived from the

main theories of emotion. If arousal is determining the attentional bias (Anderson, 2005), then stimuli with a similar relevance that vary in arousal could differently predict the size of the attentional bias; whereas if relevance is the determining property, then the size of the attentional bias could be predicted by stimuli that are similarly arousing but differ in relevance (Brosch et al., 2008). Finally, if the threat is the property determining the attentional bias (Öhman & Mineka, 2001), then only threatening stimuli—and not positive emotional stimuli—should bias attention.

## Moderators Characterizing the Emotional Properties of the Stimulus

### Valence and Arousal

Circumplex theories postulate that *valence* and *arousal* are the two orthogonal dimensions underlying the large variety of emotions (Russell, 1980). The attentional model derived from this theory (Anderson, 2005) predicts that arousal is the dimension determining the attentional bias for emotional stimuli. From this assumption, one would expect that the higher the positive stimuli are on the arousal dimension, the larger the magnitude of the attentional bias, independently of the intensity of the positive valence of the stimuli. To test this prediction, we coded how arousing and how positively valenced the positive stimuli used in the studies reporting these values were.

### Relevance to Specific Concerns

Appraisal theories postulate that the stimulus itself is not determining, as the critical factor is the interaction between the stimulus and the current concerns of the individual (Lazarus, 1991). From this assumption, one would expect a bigger attentional bias when the positive stimuli are selected on the basis of a specific concern of the participant than when they are selected without considering the participant's concerns (Brosch et al., 2008). To measure how this factor modulates attentional bias for positive stimuli, we controlled whether the experimenters considered a specific concern of their participant (e.g., being hungry, craving chocolate, and being homo-or-heterosexual) when they chose the positive stimuli (e.g., food, chocolate, and same-or-opposite gender erotic stimuli). Therefore, we coded whether the positive stimuli were selected on the basis of their *relevance to specific concerns* or *not*.

### Types of Positive Stimuli

Different types of stimuli have been used to investigate attentional bias for positive stimuli. Initially, several experiments used (a) *smiling facial expressions* inspired by experiments using fearful and angry faces to investigate attentional bias toward negative stimuli. However, smiling facial expressions might have a much lower level of relevance to the observer compared with fearful and angry expression: Whereas fearful and angry expressions reflect their corresponding emotional feeling, smiling expressions more often reflect other experiences than happiness, such as embarrassment, nervousness, or simple politeness (Ambadar, Cohn, & Reed, 2009). Therefore, several authors preferred to use positive stimuli with a higher level of relevance to biological source concerns such as (b) nourishment (the use of *food*), (c) reproduction (the use of

erotic or attractive stimuli), and (d) offspring caretaking (the use of stimuli related to *babies or children*). Other studies used stimuli that are not related to biological concerns, but that have acquired their positive value and relevance through socialization; such stimuli include (e) *monetary reward* and (f) affective stimuli related to the *self* (e.g., first name, or first name of significant others), these kinds of stimuli have been recognized to universally have a positive affective value across healthy individuals of different cultures (Yamaguchi et al., 2007). Finally, some experiments used sets of stimuli composed of (g) a *mix* of stimuli (e.g., photos illustrating sporting activities or happy families) that are selected on the basis of their positive value, without considering their relevance to the observer.

### Intrinsic Properties of the Stimulus

Emotional stimuli often have peculiar perceptual properties (e.g., big eyes of a baby face). The role played by these intrinsic perceptual properties on attentional bias for emotional stimuli has been largely debated in the literature. Emotional content and low-level perceptual characteristics have been proposed to represent two independent sources of influence on attention (Brosch et al., 2011; Pourtois et al., 2013). However, some authors (Calvo & Nummenmaa, 2008) have suggested that some intrinsic low-level perceptual characteristics of positive stimuli, such as the open mouth of a smiling face, play a fundamental role in attentional selection (for a meta-analysis see Nummenmaa & Calvo, 2015). Whereas several studies used emotional stimuli that are perceptually salient (e.g., smiling face, babies), others used neutral stimuli without perceptual salience that acquired emotional value by being associated with a positive emotional event, thereby dissociating the emotional value from the low-level perceptual characteristics. Therefore, we decided to assess how attentional bias for positive stimuli varies according to the intrinsic characteristics of the stimulus by coding two moderators: (a) the *positive value* (intrinsic or acquired) and (b) the *format of the stimulus* (word, illustration, or photos).

### Summary

In summary, accumulating evidence demonstrates that attention is biased toward emotional stimuli. According to some theories emotional attention represents a source of influence of attentional selection distinct from exogenous and endogenous attention that operates rapidly and independently of voluntary processes (Brosch et al., 2011; Pourtois et al., 2013; Vuilleumier, 2005), whereas for other theories emotional attention require at least some degree of voluntary resources (Lavie, 2005; Pessoa, Kastner et al., 2002; Pessoa, McKenna et al., 2002). Models of emotional attention derived from theories of emotion (Anderson, 2005; Brosch et al., 2008; Öhman & Mineka, 2001) propose different psychological mechanisms underlying the influence of emotion on attention. Whereas they all predict attentional modulation by negative threatening stimuli, they have different predictions for positive stimuli. Therefore, we had three main goals in the present meta-analysis. The first was to investigate whether attention is biased toward positive stimuli. The second was to investigate how the effect size of the attentional bias varies according to the characteristics of the attentional measure used in the study (e.g., Is the attentional bias

larger if it is measured at early stages of attentional processing compared with late stages? Is the attentional bias larger in an attentional paradigm that targets early rather than later stages of attentional biases?). The last goal of this meta-analysis was to investigate how the effect size of this attentional bias varies according to the characteristics of the emotional stimulus used in the study (e.g., Do positive stimuli elicit a larger bias if they are high in the arousal dimension? Do positive stimuli elicit a larger attention bias if they are relevant to the participants' concerns compared with when they are not?).

### Hypotheses

We predicted that, across different studies, attention is biased toward positive stimuli compared with neutral stimuli. Moreover, we predicted that the attentional bias varies according to the moderators characterizing the type of attentional bias and the moderators characterizing the emotional stimulus.

For the type of attentional bias, on the basis of the conceptualization of the influence of emotional stimuli on attention described earlier (Pourtois et al., 2013; Vuilleumier, 2005), we predicted that the emotional influence would already appear during early stages of attentional processing that are not yet influenced by voluntary processes. More precisely we predicted that attentional bias for positive stimuli would be particularly strong in (a) paradigms measuring rapid initial orienting rather than late difficulty in disengaging attention, (b) behavioral paradigms using shorter (i.e., 120 ms) rather than longer exposure times (i.e., more than 250 ms), and (c) experimental paradigms targeting early stages of attentional bias (e.g., RSVP task) rather than later stages of attentional bias (e.g., emotional Stroop task).

For the moderators characterizing the emotional stimulus, we formulated predictions based on different attentional models derived from theories of emotion. Based on attentional models (Anderson, 2005) derived from circumplex theories of emotion (Russell, 1980; Yik et al., 1999), we predicted that (a) the magnitude of the attentional bias varies according to the arousal dimension, independently of the valence dimension.

Based on attentional models (Brosch et al., 2007, 2008; 2013) derived from appraisal theories of emotion (Sander, Grandjean, & Scherer, 2005; Scherer et al., 2001), we predicted that attentional bias is not moderated by the intrinsic low-level perceptual characteristics, but rather by the relevance of the stimulus for the current concerns of the observer. More particularly, we hypothesized that the influence of positive stimuli on attention is larger (b) when the positive stimulus is selected for a specific concern of the observer than when it is not and (c) when the type of positive stimulus can be considered as generally relevant to a common concern shared across individuals than when it conveys several meanings without being clearly relevant to a common concern.

### Method

#### Inclusion Criteria

To select the studies that are included in this meta-analysis, we used seven criteria:

1. The article had to be written in English.



2. Only original data collected from healthy adults before the end of December 2013 were included. Studies investigating clinical populations (e.g., related to anxiety or eating disorders) were included only when the data from a control group of healthy participants were available. Studies conducted on participants younger than 18 years old were not included (Veenstra & de Jong, 2012).
3. The study had to use a paradigm measuring involuntary attentional orienting (i.e., dot probe detection, spatial cuing, visual search, free viewing, rapid visual serial presentation, double task, and their different adaptations) toward visual stimuli.
4. The dependent variable in the included studies had to consist of behavioral measures (i.e., RTs, detection accuracy), eye movements, or ERPs. When studies reported both behavioral measures and ERPs or behavioral measures and eye movements, only ERPs and eye movement measures were included because generally when these measures are recorded, the paradigm is specifically designed for them (e.g., Brosch et al., 2008; Isaacowitz, Wadlinger, Goren, & Wilson, 2006a; Pourtois et al., 2004).
5. The difference between positive stimuli and neutral stimuli could be assessed and tested. All studies comparing positive stimuli with any stimuli other than neutral (i.e., negative stimuli or stimuli with different affective valences) were not included, because the comparison of attentional bias toward positive stimuli and other types of emotional stimuli is beyond the scope of the present meta-analysis.
6. The contrast of interest—the difference between positive and neutral stimuli—had to be assessed and tested through a within-subject design. Very few studies tested the contrast of interest with a between design (Mak-Fan, Thompson, & Green, 2011; Ogawa & Suzuki, 2004); given the potential bias in combining between and within designs in the same meta-analysis (Morris & DeShon, 2002), we decided not to include studies that used a between-subjects design.
7. Data that allow the computation of an effect size based on a statistic such as  $t$ ,  $F$ , or  $p$  values had to be provided. When the contrast of interest was tested, but only the threshold of a  $p$  value was reported, the effect size was extracted by assuming that the  $p$  value (e.g.,  $p < .05$ ) was equal to the reported threshold. If the contrast of interest was tested and reported as being nonsignificant, but no exact statistic was given, we computed an estimated effect size by assuming  $p = .5$ . This conservative approach (Rosenthal, 1991) allows a better representation of the existing literature and was used only when it was possible to determine the direction of the effect through the provided descriptive statistics (15.22% of cases; for a similar procedure, see Bar-Haim et al., 2007). In cases in which the contrast of interest was not directly tested

through a planned test (e.g., positive vs. neutral), but through a main effect test that included other modalities (e.g., main effect of valence: Positive, negative, or neutral), the effect size for the contrast of interest (i.e., positive vs. neutral) was extracted through the maximum possible contrast  $F$  method (MPC- $F$ ; Rosnow & Rosenthal, 1996). The method used to extract the effect size (i.e.,  $F$ ,  $t$ ,  $p$ , and MPC- $F$ ) was entered as a control moderator and the between-groups homogeneity statistic revealed a significant effect ( $Q_B = 10.819$ ,  $p = .012$ ). Effect size extracted through  $p$  value were smaller ( $Q_B = 5.979$ ,  $p = .014$ ) than those extracted with the other methods that did not significantly differ from each other ( $Q_B = 4.996$ ,  $p = .098$ ). This was because of the fact that the  $p$  value was often reported for nonsignificant results.

From these criteria, we were able to select 150 articles (108 published, 42 unpublished), with a total of 243 studies (186 published, 57 unpublished) that had been conducted on 9,120 participants between July 1976 and December 2013. All studies included in the meta-analysis constituted independent samples; therefore, data from the experiment of Anderson and Yantis (2013) were not included, because their participants ( $N = 13$ ) took part in previous experiments (Anderson et al., 2012; Anderson, Laurent, & Yantis, 2013).

### Literature Search Strategy

The literature search strategy was performed in two stages. First, we searched for published studies. Initially, potential studies were identified through a search in the electronic Web of Science database. We searched for all available records until December 2013, using the following combinations of keywords: (*emotion* OR *affect* OR *arousal* OR *positive* OR *motivation*) AND (“*dot probe*” OR “*spatial cuing*” OR “*spatial cueing*” OR “*singleton* AND *attention*” OR “*visual search task*” OR “*Stroop task* AND *attention*” OR “*attentional blink*”) with “*participants*” OR “*subjects*” OR “*patients*.” The research yielded 592 hits. Subsequently, we consulted several review articles for additional relevant studies (Anderson, 2013; Bar-Haim et al., 2007; Becker, Anderson, Mortensen, Neufeld, & Neel, 2011; Brosch et al., 2010; Frewen, Dozois, Joanisse, & Neufeld, 2008; Frischen, Eastwood, & Smilek, 2008; Klinger, 1975; Weierich et al., 2008; Yiend, 2010). Moreover, the reference sections of the articles included in the meta-analysis were systematically consulted for the same purpose. These researches yielded 123 hits (after the removal of doubles) for a total of 715 articles.

The process of winnowing these 715 articles proceeded in two steps (see Figure 1). Step 1 involved two raters (graduate and postgraduate levels) who are authors of this article, and read all abstracts of the articles. Articles were included if the following criteria were satisfied: (a) They contained original data collected on a healthy human population; (b) a paradigm measuring involuntary attentional orienting toward visual stimuli was used; (c) attentional bias was measured through behavioral measures (i.e., RTs, detection accuracy), eye movements or ERPs; and (d) if positive visual stimuli were used. In case of doubt, the criterion was considered as satisfied and the article was further inspected. Both raters first read the same 20% of the abstracts, the overall



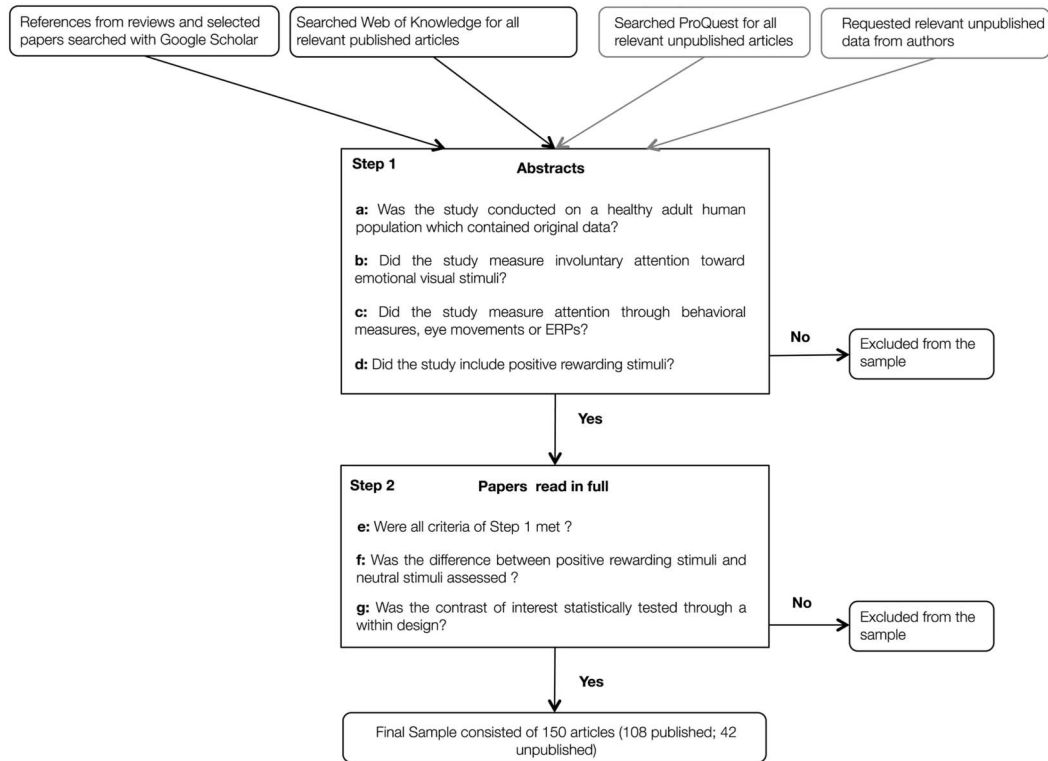


Figure 1. Flowchart illustrating the literature search and the winnowing process.

raters agreement was very high (Cohen's  $k = .83$ ). The disagreements were discussed and a consensual solution was used. One rater read the remaining abstracts: In total, 223 articles survived Step 1.

Step 2 involved one rater (graduate level) who is an author of this article, and read the remaining article in full controlling for the following criteria: (e) The method sections met all Step 1 criteria; (f) the difference between positive and neutral stimuli in the involuntary attention orienting was measured; and (g) statistically tested using a within design. 100 articles survived Step 2 and were included in the meta-analysis.

Second, we searched for unpublished studies. Initially, potential unpublished theses were identified through a search in the electronic ProQuest Dissertations & Theses database. We searched for all available records until December 2013 using the same keywords as for published studies. Because this search yielded 29,117 hits, we further specified our search criterion by including only theses that contained the terms *attention* AND *affect* OR *emotion* OR *motivation* OR *arousal* in the abstract. This reduced the hits to 664. These 664 theses were winnowed according to the same procedure used for published articles: 103 theses survived Step 1 and 44 theses survived Step 2. Only those that survived Step 2 were included in the meta-analysis. If a data from one of the theses' studies was published, only the published article was included (8). Additionally, we acquired unpublished results by contacting experts in the field of attentional bias for emotional stimuli. More precisely, we contacted 76 authors who published work on attentional bias toward positive stimuli that was included in the present meta-analysis during the first stage. We received 23

replies leading to 14 unpublished results, 6 of which could be included in the meta-analysis.

### Coding System and Coding Decisions

We coded 10 different moderators characterizing the stimuli, the attentional bias, and the experimental procedure (see Table 1).

For attentional bias, we coded four moderators. The first moderator was the type of attentional bias: difficulty in disengagement ( $k = 60$ ) or initial orienting ( $k = 30$ ). Attentional bias was coded as initial orienting for early ERP components (i.e., P1, N2pc, SSVEP) measured during emotional cues, for early eye movements (i.e., first saccade, saccadic capture, saccadic RT, misdirected saccade, and probability of fixate), and for valid trials of the spatial cuing task. It was coded as difficulty in disengagement for late ERP components measured during emotional cues (i.e., LPP), for late eye movements (i.e., dwelling time, fixation time, fixation ratio, and number of fixations), for invalid trials of the spatial cuing task, and for the Stroop task. The second moderator was the type of attentional paradigm used in the study: dot probe detection task ( $k = 58$ ), free viewing task ( $k = 24$ ), rapid visual serial presentation task ( $k = 24$ ), spatial cuing task ( $k = 24$ ), Stroop task ( $k = 35$ ), visual search task ( $k = 51$ ), or other adaptations of these tasks ( $k = 27$ ). The third moderator coded was the type of attentional measure. It was categorized as "direct" ( $k = 44$ ) for ERPs and eye movement measures and as "indirect" ( $k = 199$ ) for RTs and response accuracy (Field et al., 2009). The last moderator was the CTOA: less than 250 ms ( $k = 44$ ), 251–500 ms ( $k = 38$ ), or more than 500 ms ( $k = 25$ ). This last moderator was coded only

Table 1  
Summary of the Coding System

Variable	Levels
Attention	
Bias	Difficulty in disengagement; initial orienting
Paradigm	DPDT; FV; others; RSVP; SCT; Stroop; VS
Measure	Direct; indirect
CTOA	<250; 251–500; >500 ms
Stimulus	
Valence	Continuous variable
Arousal	Continuous variable
Relevance to specific concerns	Relevant; not relevant
Types of stimuli	Baby/child; erotic/attractive; food; general mixed; money; self-relevant; smiling face
Positive value	Acquired; intrinsic
Stimulus format	Illustration; photos; word

Note. CTOA = cue-target onset asynchrony; DPDT = dot probe detection task; SCT = spatial cuing task; VS = visual search; FV = free viewing; RSVP = rapid serial visual presentation.

for studies using indirect measures, since in studies using direct measures, the timing of the attentional bias can be decoupled from the stimulus exposure time. Studies in which the stimulus was displayed on the screen until the participants responded or in which the emotional and the neutral information was presented simultaneously (e.g., Stroop task) could not be coded for this moderator.

For the stimuli used as positive information, we coded six moderators. The first two moderators coded the valence and the arousal dimensions. More precisely, these moderators coded in a continuous way how pleasant and how arousing the positive stimulus was. To code these moderators, we used the ratings reported in the method section; ratings of valence, pleasantness, attractiveness, and positivity were used to reflect valence, whereas ratings of arousal, emotional intensity, subjective intensity, and activation, were used to reflect arousal. When these ratings were not reported in the method section we adopted two strategies. First, if identifiable stimuli from the IAPS or the Affective Norms for English Words (ANEW; Bradley & Lang, 1999) databases were used, we retrieved their normative valence and arousal ratings from their original databases. Second, for studies using smiling faces expressing happiness from the NimStim (Tottenham et al., 2009), the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1997) and the Picture of Facial Affect (PFA; Ekman & Friesen, 1976) databases we coded their valence and arousal based on their respective studies investigating the arousal and valence dimensions of these stimuli (Adolph & Alpers, 2010; Johnsen, Thayer, & Hugdahl, 1995).<sup>1</sup> Valence and arousal ratings were then transformed into percentages and coded in a continuous way.

The third moderator was coded on whether the positive stimuli were selected to be relevant to a specific concern of the participants. When the study used a specific positive stimulus (e.g., food, opposite sex erotic image, chocolate, and beautiful faces) according to a specific concern of the participants (e.g., hunger, heterosexuality, craving chocolate, and auto-reported level of attractiveness toward the beautiful faces) and both were measured and reported, the moderator was coded as “relevant to specific concerns” ( $k = 68$ ); otherwise it was coded as “not relevant to specific concerns” ( $k = 175$ ). Studies using stimuli such as the participants’ first name or the first name of the participants’ significant others

were also coded as “relevant to specific concerns.” The fourth moderator was coded on the type of stimulus used in the study: baby/child ( $k = 8$ ), erotic/attractive ( $k = 34$ ), food ( $k = 28$ ), general mixed ( $k = 54$ ), money ( $k = 32$ ), self-relevant ( $k = 34$ ), or smiling faces ( $k = 53$ ). For this moderator, we used the stimuli described in the Method section of the selected study. When the study used visual stimuli from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999) and reported the image numbers but not the image content, we retrieved the images from the IAPS database, coded the type of content for each, and calculated the percentage of each type of content in the set of stimuli used in the study. We then coded the moderator on the basis of the type of content that had the largest percentage.<sup>2</sup>

The fifth moderator was coded on whether the positive value of the stimulus was intrinsic ( $k = 211$ ) or acquired ( $k = 32$ ); it was considered acquired when an initially neutral stimulus acquired a value through the experimental procedure (e.g., by being associated with a positive event). The last moderator was coded on the stimulus format: illustrations ( $k = 41$ ), photos ( $k = 118$ ), or words ( $k = 84$ ).

To satisfy the requirement of independent effect sizes, only one effect size could be extracted from a given sample of participants. In several studies, it was possible to extract more than one effect size; in that case, the effect size included in the meta-analysis was selected according to the following criteria:

1. If a study tested several levels of a moderator for the same participants, we included only the effect size of the moderator that had the smallest sample; this procedure was used to enhance the power of the moderator analysis (Bar-Haim et al., 2007). More specifically, we selected

<sup>1</sup> For the IAPS and ANEW stimuli we were able to retrieve the normative value for the exact stimuli used in the study. However, for the KDEF the NimStim and PFA databases we could only retrieve the representative average rating of the smiling faces expressing happiness, but not the exact values for the subset of smiling faces used in the study.

<sup>2</sup> For the study of De Oca, Villa, Cervantes, and Welbourne (2012), there were 33.3% erotic/attractive, 33.3% baby/child, and 33.3% money stimuli. Therefore, we randomly selected one of these three categories.

initial orienting over difficulty in disengagement, relevant to specific concerns over not relevant to specific concerns, Stroop over dot probe detection task, words over photos, and 251–500 ms over more than 500 ms.

2. If a study used stimuli with different levels of positivity (e.g., mildly positive, highly positive), we selected the highest level.
3. If a study tested the attentional bias on the same participants in a neutral mood or in a different induced mood, we included the effect size extracted for participants in a neutral mood, since mood was not a moderator of interest for the scope of the present meta-analysis.
4. If the concerns were manipulated differently on the same participants (e.g., through a questionnaire and hunger induction; Talmi et al., 2013) we selected the experimental manipulation (i.e., the hunger induction) over the quasi-experimental one (i.e., questionnaire).
5. If a study contained several effects that were equally valid to the present meta-analysis and none of the aforementioned criteria applied, we calculated an effect size that reflected the average of the reported effects.

We assessed the intercoder variability by comparing the decisions of two coders (both graduate level: an author of this article and an incoming student) on 20% of the journal articles included in the meta-analysis. Cohen's  $k$  varied between .89 and 1 across the different moderators, with a mean of .93. The disagreements were discussed and a consensual solution was used for the final coding.

### Meta-Analytic Procedures

**Mean difference effect size.** The effect size index used was the Hedges'  $g$ , which represents the standardized mean difference between two conditions and which is corrected for biases given the sample size. Hedges'  $g$  was given a positive sign when the attentional bias was larger for the positive stimulus than for the neutral stimulus. When the attentional bias was larger for the neutral stimulus than for the positive stimulus, Hedges'  $g$  was given a negative sign. Values of Hedges'  $g$  of .20, .50, and .80 are interpreted as small, medium, and large, respectively (Cohen, 1988).

**Mixed model and moderator analysis.** We analyzed the data using a mixed-effects model (Borenstein, Hedges, Higgins, & Rothstein, 2011). This model combines random and fixed effects. The random-effects model is used to model the sampling error and the total homogeneity ( $Q_T$ ), whereas the fixed-effects model is used to model the moderator analysis. More specifically, the moderator analysis tests which part of the heterogeneity in the observed Hedges'  $g$  can be explained by a particular theoretical variable. In the moderator analysis, we estimated a variance of true effect sizes across studies ( $T^2$ ) by pooling the variance across subgroups, since we did not anticipate a larger variance in a particular subgroup compared with others (Borenstein et al., 2011). All of the analyses were computed with Comprehensive Meta-Analysis software, version 3 (Biostat, Englewood,

NJ). The meta-analysis is based on within-design studies that compare the attentional bias of the same participants in the positive and neutral conditions. Therefore, in the estimation of the effect size, the correlation between the two conditions is critically important: The larger the correlation between the two conditions, the smaller the effect size (Dunlap, Cortina, Vaslow, & Burke, 1996). Nonetheless, this correlation is never reported in published studies; thus, as suggested by Dunlap et al. (1996), we estimated the correlation to be .75.

## Results

### Characteristics of the Studies

The Appendix summarizes the characteristics of the studies that contributed to the primary meta-analysis. The data set was screened for outliers, revealing one study that had an effect size larger than 4  $SDs$  from the mean (Ciesielski, Armstrong, Zald, & Olatunji, 2010). This study was removed from the moderator analyses (see Bar-Haim et al., 2007, for a similar procedure), because the moderator analysis is a parametric test that relies on the assumption of a normal distribution and can be biased by outliers (Bar-Haim et al., 2007; Borenstein et al., 2011).

### Primary Meta-Analysis

The primary meta-analysis ( $k = 243$ ,  $n = 9,120$ ) revealed a significant effect across studies, showing globally that attention is biased toward positive stimuli compared with neutral stimuli (Hedges'  $g = .258$ , confidence interval [CI] = .224–.292,  $Z = 14.82$ ,  $p < .001$ ). There was evidence for a significant variance ( $Q_T = 1138.70$ ,  $p < .001$ ,  $I^2 = 78.74$ ) in the large sample of effect sizes, which made it possible to conduct the moderator analysis.

**Publication bias.** The funnel plot of the individual studies against the  $SE$  of the effect size revealed a slight asymmetry (see Figure 2), the Egger's test indicating a potential bias of published

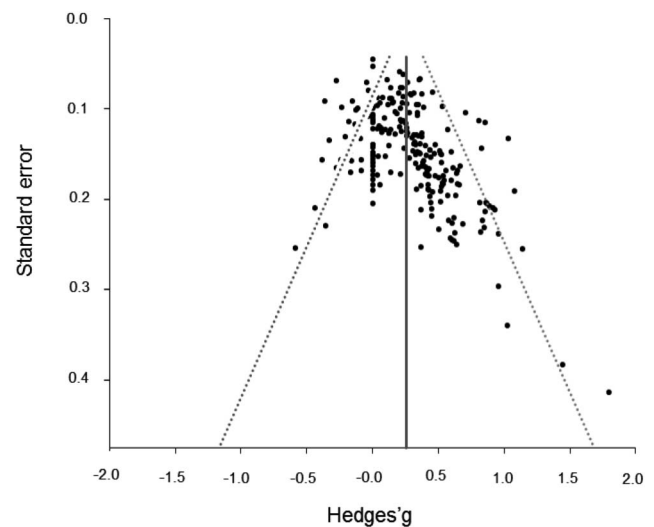


Figure 2. Funnel plot using the random-effect model illustrating the publication bias. Each study's mean weighted effect size is displayed in function of the study's average variance; the funnel illustrates the 95% CI.

studies with small samples,  $t(242) = 7.071, p < .001$ . However, after applying Duval and Tweedie's (2000) trim-and-fill correction method (54 hypothetical studies were imputed), the global effect across studies was reduced, (Hedges'  $g = .152, CI = .115-.189$ ), but remained significant. Rosenthal's Fail-Safe N was 12,245, suggesting that there would need to be more than 10,000 hypothetical studies with a zero effect added to the meta-analysis to make the difference across all studies statistically nonsignificant.

### Moderator Analyses of Attentional Bias Characteristics

**Attentional bias subcomponents.** Attentional bias for positive stimuli was larger when initial orienting was measured compared with when difficulty in disengagement was measured ( $Q_B = 4.091, p = .043$ ), although the effect size was significant in both cases (see Table 2 and Figure 3a). The measure (direct or indirect) could represent a potential bias in this particular analysis, because almost all studies assessing initial orienting used direct measures of attentional bias, whereas studies assessing difficulty in disengagement used both direct and indirect measures. To exclude this possibility, we ran the same analysis but including only studies that used direct measures, which again revealed a larger attentional bias for measures of initial orienting ( $k = 22$ , Hedges'  $g = .351, CI = .251-.451$ ) compared with measures of difficulty in disengagement ( $k = 18$ , Hedges'  $g = .219, CI = .094-.305, Q_B = 4.231, p = .040$ ).<sup>3</sup>

**Attentional paradigm.** The between-group homogeneity test revealed that the attentional paradigm significantly moderates the magnitude of attentional bias for positive stimuli ( $Q_B = 58.339, p < .001$ ; see Table 2 and Figure 3b). As predicted, in experimental paradigms targeting early stages of attentional bias, such as the RVSP task, there was a larger effect size compared with those targeting later stages, such as the Stroop task ( $Q_B = 25.954, p < .001$ ). However, the RVSP yielded a larger effect size not only compared with the Stroop task, but also compared with all other attentional paradigms pooled together (Hedges'  $g = .225, CI = .192-.259, Q_B = 23.336, p < .001$ ).

**Measure.** The moderator analysis did not reveal a significant difference between the effect sizes in studies using direct measures and studies using indirect measures ( $Q_B = 1.970, p = .160$ ; see Table 2).

**Cue-target onset asynchrony.** The moderator analysis tested the prediction that in studies using indirect measures of attention, a shorter CTOA would produce a larger effect size of attentional bias for positive stimuli. The between homogeneity test revealed a main effect of CTOA ( $Q_B = 7.507, p = .023$ ; see Table 2 and Figure 3c). A specific contrast showed that a CTOA shorter than 250 ms yielded a larger effect size compared with a CTOA longer than 250 ms ( $Q_B = 7.243, p = .007$ ; see Table 2).

### Moderator Analyses of the Emotional Properties of the Stimulus

**Valence.** A meta-regression tested the prediction that the more positive the stimulus is in the valence dimension, the larger the attentional bias. The model homogeneity statistic revealed that valence intensity was not a significant predictor of the attentional bias' magnitude ( $Q_M = 0.10, p = .705$ ; see Figure 4a).

**Arousal.** Similarly to the previous analysis, a meta-regression tested the prediction that the more a stimulus is arousing, the larger the attentional bias. The model homogeneity statistic showed a marginal effect suggesting the magnitude of the attentional bias might increase as a function of the positive stimulus' arousal dimension ( $Q_M = 2.17, p = .099$ ; see Figure 4b).

**Relevance to specific concerns.** The analysis tested the prediction that the effect of the attentional bias for positive stimuli is stronger when the positive stimulus is selected to be relevant to a specific concern of the participant. The between-group homogeneity statistic revealed that, as predicted, when the positive stimuli were relevant to the participant's specific concerns, the attentional bias was larger compared with when the positive stimuli were selected without specifically considering the participant's concerns ( $Q_B = 15.336, p < .001$ ; see Table 3 and Figure 4c).

**Types of positive stimuli.** The type of positive stimulus was an important moderator of attentional bias for positive stimuli ( $Q_B = 41.074, p < .001$ ). Table 3 illustrates how, as predicted, the stimuli that could convey several meanings; thus being less relevant to a common concern (i.e., smiling faces and general mixed stimuli) elicited smaller, but still significant, effect sizes compared with the stimuli that were more clearly relevant to a common concern (i.e., self-relevant, money, erotic/attractive, and baby/child and food;  $Q_B = 28.018, p < .001$ , for the specific contrast). However, stimuli of food produced an unexpectedly small effect (see Table 3 and Figure 5b). Because the relevance of food stimuli can vary idiosyncratically according to the physiological state of the observer (e.g., hunger), we ran a supplementary analysis with food stimuli ( $k = 28$ ) that revealed that the attentional bias for food stimuli was significantly larger when the relevance of the stimulus for the specific concerns of the participants was considered (Hedges'  $g = .351, CI = .225-.477$ ), than when the stimulus was not relevant to the participant's specific concerns (Hedges'  $g = .112, CI = .007-.216, Q_B = 8.258, p = .004$ ).

**Stimulus format.** Words, photos, and illustrations of positive stimuli yielded an attentional bias of different magnitude ( $Q_B = 6.877, p = .032$ ; see Table 3 and Figure 5a). More precisely, words yielded a significantly smaller attentional bias than illustrations and photos taken together ( $Q_B = 6.914, p = .009$ ) which did not statistically differ from each other ( $Q_B = 0.01, p = .920$ ).

**Positive value.** The attentional bias for stimuli that had an intrinsic positive value was not significantly different from those that were intrinsically neutral but acquired positive value by being associated with a positive event ( $Q_B = 2.228, p = .130$ ). In both cases, there was a significant bias for positive over neutral stimuli (Hedges'  $g_s = .242$  and  $.320$ , respectively,  $ps < .001$ ; see Table 3).

### Direct Comparison of Valence, Arousal, and Relevance to Specific Concern

Previous literature (Northoff et al., 2009) showed that very often arousal and relevance are correlated dimensions; this was also the case for our moderators: Stimuli selected to be relevant to the participant's specific concerns were rated as being more arousing than stimuli selected without specifically considering the partici-

<sup>3</sup> The study of Newman (2011) was excluded from this analysis, because on the distribution of the effect sizes using direct measures it was an outlier (i.e., more than 2 SD from the mean) with a large standard residual.



Table 2  
Summary of Results of the Moderators of Attentional Bias Characteristics

	<i>k</i>	Hedges' <i>g</i>	95% CI	<i>Q<sub>w</sub></i>	<i>Q<sub>B</sub></i>
Bias					4.091*
Initial orienting	30	.301***	.210–.393	92.560***	
Difficulty in disengagement	60	.188***	.127–.249	287.407***	
Paradigm					58.339***
Rapid serial visual presentation	23	.512***	.404–.621	86.924***	
Others	27	.358***	.262–.454	96.038***	
Visual search	51	.339***	.268–.410	154.095***	
Free viewing	24	.285***	.190–.381	114.978***	
Spatial cuing task	24	.158**	.061–.255	72.530***	
Stroop	35	.154***	.077–.231	154.667***	
Dot probe detection task	58	.127***	.065–.181	209.821***	
Paradigm: Planned comp.					25.954***
Rapid serial visual presentation	23	.513***	.404–.626	86.924***	
Stroop	35	.154***	.074–.235	154.667***	
Measure					1.970
Direct	44	.301***	.224–.379	158.664***	
Indirect	198	.240***	.203–.276	888.531***	
CTOA					7.507*
250–	43	.305***	.222–.389	251.129***	
500+	25	.187**	.082–.293	110.083***	
251–500	38	.144**	.060–.228	125.415***	
CTOA: Planned comp.					7.243**
250–	43	.305***	.222–.387	251.129***	
250+	63	.160***	.095–.225	235.526***	

Note. Hedges' *g* values are the standardized differences between the neutral and the positive emotion conditions; CI = confidence interval; *Q<sub>w</sub>* values represent the within group homogeneity statistic; *Q<sub>B</sub>* values represent the between group homogeneity statistic; *k* values are the number of effect sizes; comp. = comparison. \*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .

pant's concerns ( $Z = 3.27$ ,  $p = .001$ ). Therefore, we decided to directly compare the valence, arousal, and relevance moderator through a series of meta-regression models. This analysis was only run on studies that could be coded for the all three moderators, the sample was thereby drastically reduced ( $k = 85$ ). Because the hypothesis tested here had a clear theoretical direction,  $p$ -values were one-tailed. Moreover, analogous to the previous analysis, a random-effect model was used to estimate the sampling error and then  $Z$  values were adapted to the random-effect model to estimate the significance of individual covariates (Borenstein et al., 2011).

In the first model, we only inserted valence as a covariate. The model was not statistically significant ( $Q_M = 0.06$ ,  $p = .402$ ),

confirming that the intensity of stimulus' positive valence was not a significant predictor of the magnitude of the attentional bias.

Subsequently, we created a second model in which we added arousal as a covariate. The whole model was marginally significant ( $Q_M = 4.18$ ,  $p = .061$ ). Tests of individual covariates revealed that arousal was a significant predictor of the magnitude of the attentional bias ( $Z = 2.03$ ,  $p = .021$ ), even when the variance explained by valence was statistically held constant, whereas valence remained a nonsignificant predictor ( $Z = -1.03$ ,  $p = .151$ ) when the variance explained by arousal was statistically held constant.

Finally, we created a third model in which we added relevance to specific concerns as a covariate. The whole model was signif-

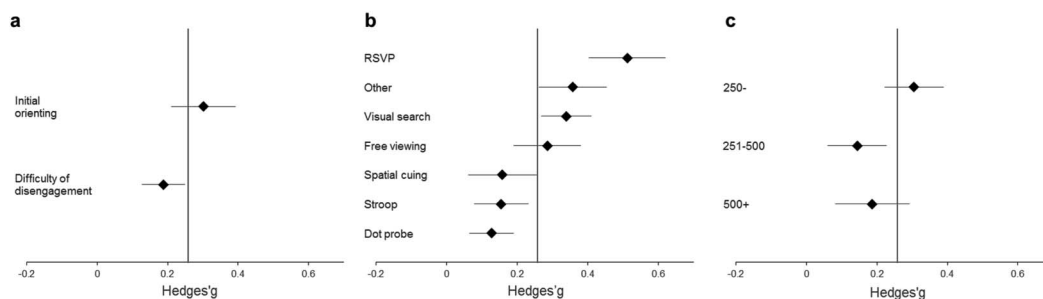


Figure 3. Forest plots illustrating the variations of the attentional bias' magnitude toward positive stimuli as a function of (a) the type of attentional bias; (b) the types of attentional paradigms (c) the cue target onset asynchrony. Means (diamond-shape points) and 95% CIs (error bars) and averaged overall effect (reference line) are displayed.

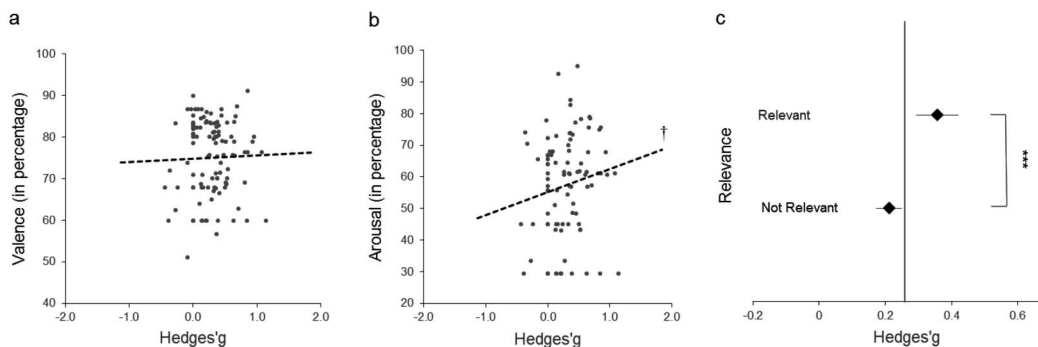


Figure 4. (a) Effect sizes ( $k = 112$ ) of the attentional bias displayed as a function of the valence rating (in percentage) of the positive stimuli; (b) effect sizes ( $k = 91$ ) displayed as a function of the arousal ratings (in percentage) of the positive stimuli; (c) average effect sizes of the attentional bias when the positive stimuli were relevant to specific concerns of the participants (i.e., relevant;  $k = 68$ ) and when the positive stimuli were selected without considering the participants' concern (i.e., not relevant;  $k = 174$ ), the reference line represents the averaged overall effect size and error bars represent 95% confidence intervals.  $^{\dagger} p < .1$ .  $*** p < .001$ .

icant ( $Q_M = 7.10$ ,  $p = .034$ ). Tests of the individual covariates revealed that when the variance explained by the other covariates was statistically controlled, relevance to specific concerns was the only significant moderator predicting the magnitude of the attentional bias ( $Z = 1.69$ ,  $p = .045$ ). More precisely the analysis revealed that: (a) Relevance to specific concerns was a significant predictor of the magnitude of the attentional bias ( $Z = 1.69$ ,  $p = .045$ ), even when the variance explained by valence and arousal was statistically held constant; (b) arousal became a nonsignificant predictor ( $Z = 1.09$ ,  $p = .137$ ), when the variance explained by relevance to specific concerns and valence was statistically held constant; and (c) valence remained a nonsignificant predictor ( $Z = -0.53$ ,  $p = .289$ ), when the variance explained by relevance to specific concerns and arousal was statistically held constant.

## Discussion

The aim of the present meta-analysis was to test whether attention is biased toward positive stimuli compared with neutral stimuli and to how the size of this effect was modulated by variables that address important current theoretical debates in both attention and emotion research. Results indicate that across all studies there is a significant bias for positive stimuli. The overall effect was modest (Hedges'  $g = .258$ ), and the high heterogeneity suggested that the bias for positive stimuli might significantly vary under different circumstances. We aimed at modeling these factors in moderator analyses by coding the characteristics of the emotional stimuli and the attentional bias.

### Role of the Characteristics of Attentional Bias

Consistent with the current conception of emotional attention (Pourtois et al., 2013; Vuilleumier, 2005), the analyses of the moderators characterizing attentional bias presented here suggest that it occurs rapidly, involuntarily, and during early stages of attentional processing.

First, the moderator analysis shows that attentional bias for positive stimuli is larger when it is measured on the initial orienting component rather than on the difficulty in disengagement

component. This finding indicates the rapidity and the involuntary aspect of the bias, because initial orienting is conceived as a preselective and involuntary mechanism, whereas difficulty in disengagement is conceived as a postselective mechanism that might already be influenced by the intention of the observer (Theeuwes, 2010; Theeuwes & Belopolsky, 2012). Note that this specific moderator analysis could be conducted on a smaller set of effect sizes ( $k = 90$ ) compared with the total sample of effect sizes ( $k = 243$ ), because the coding of this moderator strictly depended on the type of paradigm used in the study.

Second, the moderator analysis of the CTOA of paradigms using indirect measures ( $k = 106$ ) indicates that using a CTOA shorter than 250 ms yields larger attentional bias for positive stimuli compared with a CTOA longer than 250 ms or 500 ms. This finding also supports the hypothesis that attentional bias occurs rapidly and influences mainly the first attentional shift that occurs before 150 ms (Weierich et al., 2008). If an attentional shift takes about 150 ms, measures of attentional bias taken after 250 ms reflect the second, third, or even later attentional shifts that are more likely to be influenced by voluntary processes (Theeuwes, 2010; Theeuwes & Belopolsky, 2012; Weierich et al., 2008). This CTOA finding is complementary to the previous one, similarly suggesting that positive stimuli modulate the initial orienting component of attentional bias more than they modulate difficulty in disengagement.

Finally, the moderator analysis indicates that attentional bias is significantly larger in the rapid serial visual presentation (RSVP) task compared with all other attentional tasks. This is consistent with the two previous findings, because it has been proposed that the RSVP task is likely to reflect a rapid attentional bias that can be assimilated to initial orienting (Field & Cox, 2008). Note, however, that while we predicted a specific difference between the RSVP task and the Stroop task, which is known to reflect late attentional processes, we did not predict a general advantage of the RSVP task over all other tasks. It is possible that the RSVP task yields larger effect sizes because the CTOA is consistently short (i.e., at lag 2, the CTOA is almost always shorter than 250 ms), whereas in the other tasks, this parameter often varies (e.g., 100 or

Table 3  
Summary of Results of the Moderators of Emotional Properties of the Stimulus

	<i>k</i>	Hedges' <i>g</i>	95% CI	$Q_W/Q_R$	$Q_B/Q_M$
Valence	112			524.88***	0.10
Arousal	91			452.25***	2.71 <sup>†</sup>
Relevance to specific concerns					15.336***
Relevant	68	.357***	.294-.419	195.720***	
Not-relevant	174	.211***	.172-.283	822.587***	
Types of stimuli					41.074***
Baby/child	8	.450***	.265-.633	5.201	
Erotic/attractive	33	.415***	.327-.502	215.314***	
Money	32	.363***	.271-.455	157.001***	
Self-relevant	34	.286***	.200-.372	74.487***	
Food	28	.216***	.122-.310	79.716***	
General mixed	54	.173***	.107-.239	253.834***	
Smiling face	53	.135***	.066-.204	177.985***	
Types of stimuli: Planned comp.					28.018***
Money; baby/child; erotic/attractive; food; Self relevant	135	.330***	.286-.373	563.353***	
Smiling faces; general mixed	107	.155***	.107-.202	434.205***	
Positive value					2.288
Acquired	32	.320***	.225-.416	88.604***	
Intrinsic	210	.242***	.206-.277	967.743***	
Stimulus format					6.887*
Photo	117	.285***	.198-.364	610.558***	
Illustration	41	.281***	.238-.333	124.684***	
Word	84	.192***	.137-.247	306.891***	
Stimulus format: Planned comp.					6.914**
Illustration and photo	158	.284***	.243-.325	735.581***	
Word	84	.192***	.137-.247	360.891***	

Note. Hedges' *g* values are the standardized differences between the neutral and the positive emotion conditions; CI = confidence interval;  $Q_W$  and  $Q_R$  values represent the within group homogeneity statistic in group comparisons and residual variability in meta-regression, respectively;  $Q_B$  and  $Q_M$  values represent the between group homogeneity statistic in group comparison and the model homogeneity statistic in meta-regression; *k* values are the number of effect sizes; comp. = comparison.

<sup>†</sup>  $p < .1$ . \*  $p < .05$ . \*\*  $p < .01$ . \*\*\*  $p < .001$ .

500 ms in the dot probe detection task), leading to a larger noise that reduced the average size of the effect. Another aspect that distinguishes the RSVP task from all others is the fact that it directly tests the temporal aspect of attentional selection; thus, it is

also possible that the temporal selection of attention is particularly sensitive to the influence of positive stimuli.

**Implications for theories of emotional attention.** Different moderators analyses convergently suggest that positive stimuli



Figure 5. Forest plots illustrating the variations of the attentional bias' magnitude toward positive stimuli as a function of (a) the format in which the positive stimuli were presented, and (b) the types of positive stimuli. Means (diamond-shape points) and 95% confidence intervals (error bars) and averaged overall effect (reference line) are displayed.

influence attentional selection at early stages. This result contributes to the current debate on the role of voluntary processes on attentional bias for emotion: While some scholars (Lavie, 2005; Pessoa, Kastner et al., 2002; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002) postulate that this attentional bias for emotion requires some degree of voluntary processing, other scholars (Vuilleumier, 2005, 2015; Pourtois et al., 2013) instead suggest that it is independent of voluntary processes. By showing that the emotional effects on attention are not only already significant during early stages of attention, but also larger compared with later stages, our finding corroborates the hypothesis that emotional effects on attention do not require voluntary processing (Vuilleumier, 2005, 2015) and represent a distinct source of influence on attentional resource allocation (Pourtois et al., 2013). This rapid and involuntary attentional bias for emotional stimuli has been proposed to be underlain by an enhancement of the cortical perceptual representation rendering the stimulus more salient and thus more likely to access the conscious resources of the individual, and to ultimately influence behavior. This affective modulation seems to operate through a neuronal network in which the amygdala plays an important role (Vuilleumier, 2005). A large part of the research on the neuronal network of emotional attention has been conducted on negative threatening stimuli. Therefore, for the moment, the role of the amygdala in attentional bias for positive rewarding stimuli remains unsolved. However, the amygdala being a vital structure of the reward circuit (Murray, 2007) and having direct feedback to the visual areas (Amaral, Behnia, & Kelly, 2003) seems likely to play a similar role in attentional bias for positive rewarding stimuli.

### Role of the Properties of the Emotional Stimulus in Biasing Attention

The main conclusion from the analyses of the moderators characterizing the properties of the positive stimuli is that the stimulus per se matters less than its interaction with the observer's current concerns.

The analyses indicate that the attentional bias is smaller when the positive stimulus is presented as a word compared with when it is presented as a photograph or an illustration. This is consistent with other studies investigating attentional bias for affective stimuli (Pishyar, Harris, & Menzies, 2007) that have also found a reduced bias for words compared with other formats. However, the low-level perceptual characteristics of the positive stimulus (e.g., the big eyes of babies' faces or the open mouth of smiling faces) do not seem to be a necessary condition for the existence of the attentional bias: The bias has similar sizes in stimuli that are intrinsically emotional and stimuli that are not perceptually salient, but that have acquired a positive value through associative learning. This finding, although not conclusive, is coherent with the proposal that the emotional content and the low-level perceptual characteristics represent two independent sources of influence on attentional selection (Brosch et al., 2011; Pourtois et al., 2013).

The present meta-analysis indicates that the attentional bias is significantly larger for babies, erotic attractive adults, money, self-related and food stimuli compared with smiling faces, and a mix of general positive stimuli. This could be because these stimuli may be relevant to common source concerns, such as nourishment (e.g., food stimuli), reproduction (e.g., erotic stimuli), or offspring

caretaking (e.g., stimuli of babies) as well as other common source concerns that have been developed through socialization (e.g., money or self-related stimuli), whereas smiling faces and a mix of general positive stimuli carrying several meanings (Ambadar et al., 2009) are less relevant to common source concerns of observers. However, this effect may also be because these stimuli (e.g., money, babies, food, and erotic stimuli) are typically reported as highly arousing (Lang et al., 1999).

The present meta-analysis shows that the magnitude of the attentional bias increases proportionally to the level of arousal of the positive stimulus; however it also demonstrates that the magnitude of attentional bias for positive stimuli is significantly larger when the type of positive stimulus (e.g., food) is relevant to a specific concern of the participants (e.g., hunger) than when it is not. The meta-regression model suggests that the relevance moderator might be a more powerful predictor of the attentional bias magnitude than the arousal moderator. Arousal lost its predictive power when the variance explained by relevance was controlled, while relevance significantly predicted more variance of the attentional bias' magnitude than arousal.

**Implications for models of emotional attention derived from emotional theories.** Emotional attention models derived from the classical theories of emotion debate on the key properties allowing the emotional stimulus to have a privileged attentional status. Results of the moderators characterizing the properties of the emotional stimulus contribute to this debate in several ways.

Results of the primary meta-analysis contradict the "threat hypothesis" (Öhman & Mineka, 2001) according to which attention is exclusively biased toward stimuli that have intrinsic perceptual features characteristic of threats to the species for which organisms have been biologically prepared. The present meta-analysis indicates that attention is also biased toward positive stimuli and that this bias occurs rapidly and independently of voluntary processes.

Our results are consistent with both the "arousal hypothesis" postulating that emotional attention is driven by the stimulus' potential to elicit arousal (Anderson, 2005; Russell, 1980) and the "relevance hypothesis" postulating that the psychological mechanism driving emotional attention is the detection of the stimulus relevance for the observer's concerns (Brosch et al., 2007; Frijda, 1988; Sander, Grandjean, & Scherer, 2005; Scherer, 2013). Positive stimuli that are relevant to the observer's concerns are also very often high on the arousal dimension. For this reason, the respective roles of relevance and arousal are difficult to disentangle in attentional bias for positive stimuli. Nevertheless, there is a major difference in the underlying psychological mechanisms modeled by the two respective emotion theories. Based on circumplex theories of emotion, it has been suggested that arousal directly determines attentional bias, whereas according to appraisal theories, it is relevance detection that determines attentional bias; it also very often elicits a motivational state reflected in a consequent physiological state of arousal that may be consciously felt. Therefore, for appraisal theories, the mechanism responsible for attentional bias resides in the emotion elicitation process, while for circumplex theories, it resides in one aspect of the emotional response.

The meta-analysis provides both indirect and direct evidence in favor of the relevance hypothesis as compared with the arousal hypothesis. Indirect evidence can be found in the fact that the results suggest that the attentional bias occurs very rapidly. There-



fore, it seems unlikely that this bias could be driven by the arousal response elicited by the positive stimulus, as such an autonomic response would take longer to occur and then be represented in the brain to influence the attention system. Note that arousal has been conceptualized as a psychophysiological reaction indexed by sympathetic activity (Schachter & Singer, 1962), but also as a general state of vigilance indexed by particular electroencephalic activity (Jones, 2003), and even as a combination of vigilance and sympathetic activity (Duffy, 1957; for a discussion, see Sander, 2013). This conceptual ambiguity complicates the analysis of the role of arousal in the emotional response. More direct evidence in favor of the relevance hypothesis as compared with the arousal hypothesis can be found in the fact that when arousal and relevance moderators were tested by statistically controlling their respective variances, only relevance remained a significant predictor of the magnitude of the attentional bias. This implies that two stimuli with similar levels of arousal predict the magnitude of the attentional bias for positive stimuli according to their relevance to the observer concerns; by contrast two similarly relevant stimuli that differ on their arousal dimension do not significantly differ in predicting the magnitude of the attentional bias for positive stimuli.

**Implications for other theories of positive emotions and attention.** The present meta-analysis contributes to another debate on the influence of positive stimuli on attention. For a long time, it has been postulated that positive stimuli, because they induce a positive affect in the observer, do broaden attention and facilitate the processing of stimuli surrounding the positive stimulus (Fredrickson, 2001). An alternative proposal postulated that positive stimuli reduce the attentional breadth if they have a high motivational value: If an individual is motivated to obtain the positive stimulus, then attentional resources will be focused on the positive stimulus despite other stimuli (Gable & Harmon-Jones, 2008; Harmon-Jones & Gable, 2009). The results of the present meta-analysis provide evidence favoring this alternative proposal as long as the early attentional processing are concerned, since they show that (a) when a positive stimulus is presented with neutral information, attention focuses on the positive information despite the neutral one; and that (b) the magnitude of this attentional bias varies proportionally to motivational variables such as relevance and arousal. However, findings of the present meta-analysis do not allow for any conclusive interpretations regarding the effect of positive stimuli on subsequent attentional processing: A broadening of attention induced by positive stimuli occurring much later after the stimulus perception would still be compatible with our findings.

The findings of this meta-analysis showing the magnitude of the attentional bias varying according to the observer's concerns is also in line with the incentive salience hypothesis, which has been developed on the basis of animal models (Berridge & Robinson, 1998, 2003). An important tenet of this model is that positive stimuli capture attentional resources, with the magnitude of this involuntary attentional capture being directly modulated by the relevance of the stimulus for physiological (e.g., hunger) and brain (e.g., mesolimbic dopamine reactivity) states (Berridge & Robinson, 1998; Robinson, Yager, Cogan, & Saunders, 2014).

Moreover, the role of the observer's concerns is also consistent with a series of recent findings showing that attention is automatically oriented toward stimuli that are motivationally relevant for

the temporary goal of the individual (Folk et al., 1992; Mazzietti, Sellem, & Koenig, 2014; Rothermund, 2003; Vogt, De Houwer, & Crombez, 2011; Vogt, De Houwer, Crombez, & Van Damme, 2013; Vogt, De Houwer, Moors, Van Damme, & Crombez, 2010; Vogt, De Houwer, & Moors, 2011). These studies have consistently demonstrated that even neutral stimuli bias attentional resources if they are relevant to a desired end state that the individual tries to achieve (Folk et al., 1992; Rothermund, 2003; Vogt et al., 2010).

### Comparison With the Attentional Bias for Negative Threatening Stimuli

It is interesting that almost all theories predicting the existence of an attentional bias for positive stimuli commonly postulate that the fundamental property allowing positive stimuli to have a privileged attentional status does not relate to their valence or hedonic value but rather to their motivational dimension (Anderson, 2005; Berridge & Robinson, 1998, 2003; Brosch et al., 2007; Brosch, Sander, et al., 2008, 2013; Gable & Harmon-Jones 2008; Harmon-Jones & Gable, 2009; Robinson et al., 2014; Vogt et al., 2011, 2013). This dimension is common to both positive rewarding and negative threatening stimuli; therefore, attentional bias for these two kinds of emotional stimuli should be similar. The extensive meta-analysis conducted by Bar-Haim and collaborators (2007) on attentional bias for negative threatening stimuli suggests that this might be the case: Similarly to our findings on positive stimuli, the bias for negative stimuli seemed to critically depend on the observer's anxious concerns. We could only compare the functioning rather than the size of the effects, because we used slightly different meta-analytic methods (e.g., we used Hedges'  $g$  rather than Cohen's  $d$ ; we focused on within designs by estimating the correlation at .75). Therefore, a direct comparison of the biases' size might be misleading.

### Limitations

In meta-analytic investigations, publication bias is one of the most common limitations because studies that obtain significant findings are more likely to be published than studies that obtain nonsignificant findings (Borenstein et al., 2011; Rosenthal, 1991), and this produces an overrepresentation of the significance effect. We tried to circumvent this limitation in several ways. First, we searched for unpublished theses, we contacted experts for unpublished data and manuscripts, and, we were able to include 57 unpublished studies in the meta-analysis. Second, we included the studies reporting nonsignificant effects without providing the statistical values as null effects; this conservative procedure is known to allow better representation of the nonsignificant effects (Rosenthal, 1991). Third, we included several cases in which attentional bias was tested on a control group that was not of interest for the main goal of the study. These types of effects are likely to be reported even if not significant, because they are presented as a control. Despite these strategies, in the present meta-analysis, evidence for a possible publication bias was found. However, the overall effect was significant even after correction with the trim-and-field procedure and Rosenthal's Fail-Safe  $N$  showed that there would need to be more than 10,000 null results to reduce the main effect to insignificance. This effect is 10 times

larger than the critical threshold ( $5k + 1$ ) proposed by Rosenthal (1991).

A second important concern in meta-analytic investigations conducted on studies using within-subject designs is the estimation of the correlations between the two conditions that are compared in the contrast of interest (e.g., positive vs. neutral stimuli). The size of this correlation directly determines the size of Hedges'  $g$  extracted on the basis of statistical values such as  $t$ ,  $p$ , or  $F$ , but is almost never reported in published studies. In Rosenthal's formula (1991), to extract effect sizes from such studies, the correlation is estimated by default at .5; However, in the present meta-analysis, we adopted a more stringent criterion, estimating this correlation at .75, as suggested by Dunlap and colleagues (1996). Note that this estimation may lead to an overestimation of the effect size in studies that have a bigger correlation and to an underestimation of studies that have a smaller correlation. This might represent a bias for the present results.

Moreover, the present meta-analysis included studies exclusively conducted on visual stimuli. Therefore, the conclusions that can be driven from this data only apply to the visual attentional system. Recently, a growing corpus of studies started exploring attentional bias for affective stimuli on different sensory modalities such as auditory perception (e.g., Asutay & Västfjäll, 2014; Brosch, Grandjean, Sander, & Scherer, 2008, 2009; Sander, Grandjean, Pourtois et al., 2005) and olfaction (e.g., Chen, Zhou, Chen, He, & Zhou, 2013). Taken together, these studies suggest that attentional bias for affective stimuli in other sensory systems is similar to the one observed in the visual system.

Finally, several studies tested the attentional bias for positive stimuli in control groups that were not of interest for their main hypothesis (e.g., a control group of healthy participants in studies investigating attentional orienting toward food in eating disorders). Therefore, although we tried to be as systematic as possible, we cannot exclude the possibility that some studies have not been included in this meta-analysis. However, with 150 publications, more than 200 independent samples, and more than 9,000 participants, this meta-analysis provides informative data.

## Conclusions

At the operational level, our findings suggest that in the investigation of attentional bias for positive stimuli, it is suitable to (a) consider the participants' concerns when choosing the emotional stimulus and (b) use attentional paradigms and measures likely to reflect the modulation of the first attentional shift. With respect to theories of attention and emotion, the present meta-analysis demonstrates that attention is biased toward positive stimuli when compared with neutral stimuli, and that this effect is larger during early than later stages of attentional processing, supporting thereby the idea that emotional stimuli are processed rapidly and independently of voluntary processes (Vuilleumier, 2005, 2015). Moreover, as predicted by the attentional model derived from appraisal theories of emotion (Brosch et al., 2007, 2008, 2013; Sander, Grandjean, & Scherer, 2005), this effect is significantly larger for positive stimuli that are relevant to the current concerns of the observer.

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**Appendix**  
**Summary of the Studies Included in the Meta-Analysis**

Study	<i>n</i>	Stimulus	Valence	Arousal	Relevance	Paradigm	<i>g</i>	95% CI
Abraham (2004)	76	Food	—	—	Not considered	Stroop	.29	.12–.45
Alexopoulos et al. (2012; Exp. 1)	27	Self relevant	—	—	Considered	SCT	.31	.04–.58
Alexopoulos et al. (2012; Exp. 2)	33	Self relevant	—	—	Considered	SCT	.26	.02–.51
Alexopoulos et al. (2012; Exp. 3)	32	Self relevant	—	—	Considered	SCT	.32	.06–.57
Alexopoulos et al. (2012; Exp. 4)	19	Self relevant	—	—	Considered	SCT	.35	.03–.67
Alpers (2008)	28	General mixed	78.88	61.66	Not considered	Free viewing	.51	.22–.80
Anderson (2005; Exp. 2; Group 1)	18	Erotic/attractive	70.00	64.29	Not considered	RSVP	.53	.17–.89
Anderson (2005; Exp. 2; Group 2)	18	General mixed	82.85	48.57	Not considered	RSVP	.40	.06–.74
Anderson et al. (2011a; Exp. 1)	26	Money	—	—	Not considered	Visual search	.47	.18–.76
Anderson et al. (2011a; Exp. 3)	24	Money	—	—	Not considered	Visual search	.52	.21–.84
Anderson et al. (2011b; Exp. 1)	18	Money	—	—	Not considered	Visual search	.54	.18–.89
Anderson & Yantis (2012; Exp. 1.)	14	Money	—	—	Not considered	Visual search	.82	.36–1.29
Anderson (2012)	13	Money	—	—	Not considered	Visual search	.44	.04–.84
Anderson, Laurent et al., (2012; Exp. 1)	21	Money	—	—	Not considered	Other	.38	.07–.70
Anderson et al. (2012)	30	Money	—	—	Not considered	Visual search	.12	–.12–.37
Anderson (2013)	11	Money	—	—	Not considered	Visual search	.45	.02–.88
Anderson et al. (2013)	16	Money	—	—	Not considered	Visual search	.96	.49–1.43
Arnell et al. (1999; Exp. 1)	12	Self relevant	—	—	Considered	RSVP	.60	.16–1.05
Arnell et al. (1999; Exp. 2a)	8	Self relevant	—	—	Considered	RSVP	1.03	.36–1.69
Arnell et al. (1999; Exp. 2b)	16	Self relevant	—	—	Considered	RSVP	.84	.40–1.28
Arnell et al. (2007; Exp. 2)	24	General mixed	80.71	64.00	Not considered	RSVP	.00	–.27–.27
Arnell et al. (2007; Exp. 1)	18	General mixed	80.71	64.00	Not considered	RSVP	.00	–.31–.31
Ashley et al., (2013)	30	General mixed	84.44	64.44	Not considered	Stroop	.13	–.12–.38
Austin & Duka (2010)	32	Money	—	—	Not considered	Free viewing	.04	–.20–.28
Bacon (2011)	41	Smiling face	59.95	29.31	Not considered	DPDT	.00	–.21–.21
Baum et al. (2013)	100	Smiling face	—	—	Not considered	DPDT	–.04	–.18–.09
Becker (2005; Exp. 1)	15	Smiling face	59.95	29.31	Not considered	Visual search	.85	.39–1.30
Becker (2005; Exp. 2)	22	Smiling face	59.95	29.31	Not considered	Visual search	.39	.08–.70
Belopolsky et al., (2011)	9	Smiling face	—	—	Not considered	Free viewing	–.36	–.80–.09
Blackmore (2011)	32	General mixed	82.78	66.89	Not considered	SCT	.00	–.24–.24
Bradley et al. (1997; Exp. 1)	20	Smiling face	—	—	Not considered	DPDT	.00	–.30–.30
Bradley et al. (1997; Exp. 2)	13	Smiling face	—	—	Not considered	DPDT	.00	–.36–.36
Bradley et al. (1998)	18	Smiling face	—	—	Not considered	DPDT	.00	–.31–.31
Brignell et al. (2009; External eating group)	19	Food	72.33	—	Considered	DPDT	.55	.20–.90
Brosch et al. (2008; EEG Exp.)	19	Baby/child	75.62	61.53	Not considered	DPDT	.26	.03–.48
Brosch et al. (2008; Behavioral Exp.)	13	Baby/child	75.62	61.53	Not considered	DPDT	.48	.14–.82
Brosch et al. (2007)	38	Baby/child	75.62	61.53	Not considered	DPDT	.62	.19–1.05
Calvo & Avero (2005)	80	Erotic/attractive	81.11	54.44	Not considered	Free viewing	.35	.06–.64
Calvo & Lang (2004; Exp. 1)	24	Baby/child	84.44	51.55	Not considered	Free viewing	.41	.11–.70
Calvo & Lang (2005; Exp. 1)	24	Erotic/attractive	80.00	60.77	Not considered	Free viewing	.31	.15–.48
Christopher (2010; Exp. 1)	12	Smiling face	67.45	45.11	Not considered	DPDT	–.44	–.85–.03
Christopher (2010; Exp. 2b)	20	Smiling face	67.45	45.11	Not considered	SCT	–.24	–.55–.07
Christopher (2010; Exp. 5a)	24	Smiling face	67.45	45.11	Not considered	Visual search	.24	–.04–.52
Ciesielski et al. (2010)	50	Erotic/attractive	75.56	75.56	Not considered	RSVP	2.34	1.84–2.83
Compton et al. (2003)	11	Erotic/attractive	82.48	84.28	Not considered	Stroop	.37	–.05–.78
Cooper & Langton (2006; Group 1)	22	Smiling face	59.93	29.31	Not considered	DPDT	–.38	–.69–.08
Cooper & Langton (2006; Group 2)	35	Smiling face	59.93	29.31	Not considered	DPDT	.20	–.03–.44
Craven-Thuss (2007)	50	General mixed	82	—	Not considered	SCT	.00	–.19–.19
Davies (1998)	60	General mixed	—	—	Not considered	Stroop	–.15	–.33–.27
de Jong et al. (2009)	67	Smiling face	68.77	43.33	Not considered	RSVP	.53	.34–.72
de Oca et al. (2012; Exp. 1)	29	Money	76.38	61.11	Not considered	RSVP	1.08	.71–1.46
de Oca et al. (2012; Exp. 2)	65	Money	76.38	61.11	Not considered	RSVP	.85	.63–1.08
de Oca et al. (2012; Exp. 3)	64	Money	76.38	61.11	Not considered	RSVP	.81	.58–1.03
Dewitte et al., (2007; Exp. 1)	59	Self relevant	—	—	Considered	DPDT	.26	.07–.44
Dewitte et al., (2007; Exp. 2)	59	Self relevant	—	—	Considered	DPDT	.16	–.02–.34
Dewitte et al., (2007; Exp. 3)	54	Self relevant	—	—	Considered	DPDT	.12	–.07–.31
Dewitte et al., (2007; Exp. 4)	62	Self relevant	—	—	Considered	DPDT	.00	–.17–.17
Dresler et al., (2009)	50	General mixed	81.33	61	Not considered	Stroop	.34	.13–.54
Drury (1997)	89	General mixed	79.14	—	Not considered	Stroop	.46	.29–.62

(Appendix continues)

## Appendix (continued)

Study	<i>n</i>	Stimulus	Valence	Arousal	Relevance	Paradigm	<i>g</i>	95% CI
di Pellegrino et al. (2011)	26	Food	85	79	Considered	DPDT	.67	.35–.99
Farley & Yen (1976)	9	General mixed	—	—	Not considered	Visual search	-.59	-1.08–.09
Feldmann-Wüstefeld et al. (2011)	24	Smiling face	68.78	43.33	Not considered	Visual search	.12	-.15–.40
Fox et al. (2001; Exp. 1)	50	General mixed	—	—	Not considered	SCT	-.11	-.31–.08
Fox et al. (2001; Exp. 2)	19	Smiling face	—	—	Not considered	SCT	-.16	-.47–.15
Fox et al. (2001; Exp. 5)	36	General mixed	—	—	Not considered	Stroop	-.13	-.36–.09
Fox et al. (2002; Exp. 2)	48	Smiling face	—	—	Not considered	SCT	-.13	-.33–.07
Gable & Harmon-Jones (2010)	29	Food	56.67	82.78	Not considered	Other	.36	.09–.64
Giel et al. (2011; Fasted)	18	Food	66.50	—	Considered	Free viewing	.41	.07–.75
Giel et al. (2011; Sated)	20	Food	64.00	—	Not considered	Free viewing	.10	-.20–.40
Golub et al. (1988)	12	General mixed	—	—	Not considered	other	.58	.14–1.01
Gronau et al. (2003; Exp. 1a)	32	Self relevant	—	—	Considered	Stroop	.34	.08–.59
Gronau et al. (2003; Exp. 1b)	32	Self relevant	—	—	Considered	Stroop	.35	.09–.60
Gronau et al. (2003; Exp. 2a)	32	Self relevant	—	—	Considered	Stroop	.05	-.18–.30
Gronau et al. (2003; Exp. 2b)	32	Self relevant	—	—	Considered	Stroop	.22	-.03–.46
Gronau et al. (2003; Exp. 3)	32	Self relevant	—	—	Considered	Stroop	.27	.02–.51
Gronau et al. (2003; Exp. 4)	20	Self relevant	—	—	Considered	Stroop	.89	.49–1.30
Gronau et al. (2003; Exp. 5)	20	Self relevant	—	—	Considered	Stroop	.04	-.25–.34
Gronau et al. (2003; Exp. 6)	30	Self relevant	—	—	Considered	Stroop	.30	.04–.56
Gronau et al. (2003; Exp. 7)	30	Self relevant	—	—	Considered	Stroop	.07	-.17–.32
Hammersley (2010; Exp. 3)	64	General mixed	86.67	72.86	Not considered	SCT	.13	-.04–.31
Harris et al. (2004; Exp. 1)	60	Self relevant	—	—	Considered	Visual search	.33	.15–.52
Harris et al. (2004; Exp. 2)	34	Self relevant	—	—	Considered	Visual search	.37	.13–.62
Harris et al. (2004; Exp. 4)	45	Self relevant	—	—	Considered	Visual search	.18	-.02–.39
Harris et al. (2004; Exp. 5)	41	Self relevant	—	—	Considered	Visual search	-.03	-.25–.18
Harris et al. (2004; Exp. 7)	63	Self relevant	—	—	Considered	Visual search	.00	-.17–.17
Harris et al. (2004; Exp. 8)	39	Self relevant	—	—	Considered	Visual search	.22	.00–.44
Harris & Pashler (2004; Exp. 1)	59	Self relevant	—	—	Considered	Stroop	.23	.04–.41
Harris & Pashler (2004; Exp. 1b)	58	Self relevant	—	—	Considered	Stroop	.39	.19–.58
Hickey et al. (2010a; EEG Exp.)	14	Money	—	—	Not considered	Visual search	.44	.05–.82
Hickey et al. (2010a; Behavioral Exp.)	20	Money	—	—	Not considered	Visual search	.33	.01–.64
Hickey et al. (2010a; Control Exp.)	14	Money	—	—	Not considered	Visual search	.41	.09–.73
Hickey et al. (2010b)	35	Money	—	—	Not considered	Visual search	.26	.02–.50
Hickey et al., (2011)	15	Money	—	—	Not considered	Visual search	.42	.05–.80
Hickey & van Zoest (2012)	18	Money	—	—	Not considered	Visual search	.42	.08–.76
Hickey & van Zoest (2013)	15	Money	—	—	Not considered	Visual search	.46	.08–.83
Hodsoll et al. (2010; White)	20	Baby/child	83.50	78.20	Considered	DPDT	.54	.20–.88
Hodsoll et al. (2010; Asiatic)	20	Baby/child	81.20	73.30	Considered	DPDT	.40	.08–.72
Hodsoll et al. (2011; Exp. 2)	24	Smiling face	—	—	Not considered	Visual search	.52	.12–.91
Holitt et al. (2010)	78	Food	—	—	Not considered	Visual search	-.03	-.19–.12
Ioannou et al. (2004)	10	Smiling face	—	—	Not considered	DPDT	.00	-.40–.40
Isaacowitz et al. (2006a; Older)	28	Smiling face	—	—	Not considered	DPDT	.41	.13–.68
Isaacowitz et al. (2006a; Younger)	32	Smiling face	—	—	Not considered	DPDT	.10	-.14–.34
Isaacowitz et al. (2006b; Older)	27	Smiling face	—	—	Not considered	Free viewing	.33	.05–.60
Isaacowitz et al. (2006b; Younger)	37	Smiling face	—	—	Not considered	Free viewing	.00	-.22–.22
Isaacowitz et al. (2008; Older)	13	Smiling face	—	—	Not considered	Free viewing	.00	-.35–.35
Isaacowitz et al. (2008; Younger)	27	Smiling face	—	—	Not considered	Free viewing	.44	.15–.72
Isaacowitz et al. (2009; Younger)	34	Smiling face	—	—	Not considered	Free viewing	.05	-.18–.28
Isaacowitz et al. (2009; Older)	29	Smiling face	—	—	Not considered	Free viewing	-.21	-.46–.05
Izotelnny (2006; Dismissing group)	21	General mixed	83.33	33.33	Not considered	DPDT	.28	-.03–.85
Izotelnny (2006; Fearful group)	18	General mixed	83.33	33.33	Not considered	DPDT	-.27	-.60–.05
Izotelnny (2006; Preoccupied group)	20	General mixed	83.33	66.66	Not considered	DPDT	.00	-.30–.30
Janer (1994)	20	General mixed	—	—	Not considered	Stroop	.00	-.30–.30
Jiang et al. (2006; Exp. 1; Hetero men)	10	Erotic/attractive	—	—	Considered	DPDT	1.45	.70–2.20
Jiang et al. (2006; Exp. 1; Hetero women)	10	Erotic/attractive	—	—	Considered	DPDT	.50	.05–.96
Jiang et al. (2006; Exp. 2; Gay men)	10	Erotic/attractive	—	—	Considered	DPDT	.62	.13–1.10
Johansson et al. (2004)	43	Food	—	—	Not considered	Stroop	.00	-.21–.21
Jormann & Gotlib (2007)	19	Smiling face	67.89	45.11	Not considered	DPDT	.50	.16–.85
Kawahara & Yamada (2004; Exp. 4)	10	Self relevant	—	—	Considered	RSVP	.61	.13–1.09
Kawahara & Yamada (2004; Exp. 5)	14	Self relevant	—	—	Considered	RSVP	.00	-.35–.35
Keil & Ihssen (2004; Exp. 1)	18	General mixed	91.11	75.55	Not considered	RSVP	.86	.44–1.28
Keil & Ihssen (2004; Exp. 3)	16	General mixed	83.89	43.11	Not considered	RSVP	.21	-.12–.55
Keil et al. (2006)	13	General mixed	87.45	78.45	Not considered	RSVP	.68	.24–1.13

(Appendix continues)



## Appendix (continued)

Study	<i>n</i>	Stimulus	Valence	Arousal	Relevance	Paradigm	<i>g</i>	95% CI
Kemps & Tiggemann (2009; Exp. 1; Cravers)	40	Food	—	—	Considered	DPDT	.24	.01–.46
Kemps & Tiggemann (2009; Exp. 1; Control)	40	Food	—	—	Not considered	DPDT	-.09	-.31–.12
Kemps & Tiggemann (2009; Exp. 2; Cravers)	53	Food	—	—	Considered	DPDT	.23	.04–.42
Kemps & Tiggemann (2009; Exp. 2; Control)	53	Food	—	—	Not considered	DPDT	-.04	-.23–.15
Koranyi & Rothermund (2012; Exp. 1)	15	Erotic/attractive	71.50	—	Considered	SCT	.43	.06–.80
Koranyi & Rothermund (2012; Exp. 2)	19	Erotic/attractive	69.00	—	Considered	SCT	.81	.41–1.21
Koven et al. (2003)	138	General mixed	—	—	Not considered	Stroop	.24	.11–.36
Krasnoperova (1998)	16	Smiling face	86.67	—	Not considered	DPDT	-.09	-.42–.24
Lamy et al. (2008; Exp. 2a)	14	Smiling face	67.89	45.11	Not considered	Visual search	.33	-.04–.70
Leclerc & Kensinger (2008; Older)	24	General mixed	78.57	57.14	Not considered	Visual search	.36	.07–.65
Leclerc & Kensinger (2008; Younger)	24	General mixed	78.57	57.14	Not considered	Visual search	.00	-.27–.27
Lee, H.-J. (2009; Exp. 1)	276	Smiling face	—	—	Not considered	Other	.13	.05–.22
Lee, H.-J. (2009; Exp. 2)	261	Smiling face	59.94	29.31	Not considered	Other	.14	.05–.22
Lee, J. (2013; Exp. 1)	17	Money	—	—	Not considered	Visual search	.52	.16–.89
Lee, J. (2013; Exp. 2)	19	Money	—	—	Not considered	Visual search	.41	.08–.75
Leland & Pineda (2006; Exp. 1)	24	Food	70.00	—	Not considered	SCT	.31	.07–.65
Leland & Pineda (2006; Exp. 2)	20	Food	70.00	—	Considered	SCT	.38	.06–.69
Leung (2008; Exp. 1)	42	General mixed	86.67	77.78	Not considered	DPDT	-.03	-.24–.18
Levens & Gotlib (2009)	24	General mixed	86.67	77.11	Not considered	Other	.44	.14–.74
Linder (2013)	21	Smiling face	67.89	45.11	Not considered	DPDT	.00	-.29–.29
Lipp et al. (2009; Exp. 2)	40	Smiling face	75	71.25	Not considered	Visual search	.21	-.01–.43
Lucas & Vuilleumier (2008)	27	Smiling face	68.77	43.33	Not considered	Visual search	.55	.15–.81
Lykins (2011)	43	General mixed	—	—	Not considered	Free viewing	.57	.33–.81
Lykins et al. (2008)	40	Erotic/attractive	—	75	Not considered	Free viewing	.83	.55–1.11
McCabe (2013; Exp. 2)	39	General mixed	—	—	Not considered	Stroop	.00	-.22–.22
Maner et al. (2003; Exp. 4; Women)	82	Erotic/attractive	75.29	—	Considered	Free viewing	.38	.22–.54
Maner et al. (2003; Men)	69	Erotic/attractive	75.29	—	Considered	Free viewing	.23	.06–.40
Maner et al. (2007; Women)	106	Erotic/attractive	83.56	—	Not considered	SCT	.26	.13–.40
Maner et al. (2007; Men)	76	Erotic/attractive	83.56	—	Considered	SCT	.20	.04–.36
Maner, DeWall et al. (2008; Exp. 2)	47	Erotic/attractive	84.78	—	Not considered	Free viewing	.17	-.03–.37
Maner, Rouby et al. (2008)	56	Erotic/attractive	82.33	—	Considered	SCT	.06	-.13–.24
Mather & Carstensen (2003; Exp. 1; Younger)	52	Smiling face	—	—	Not considered	DPDT	.00	-.19–.19
Mather & Carstensen (2003; Exp. 1; Older)	52	Smiling face	—	—	Not considered	DPDT	.21	.02–.41
Mather & Carstensen (2003; Exp. 2; Older)	44	Smiling face	—	—	Not considered	DPDT	.00	-.21–.21
Mather & Carstensen (2003; Exp. 2; Younger)	44	Smiling face	—	—	Not considered	DPDT	.00	-.21–.21
McMillian (2008)	63	Smiling face	—	—	Not considered	DPDT	.00	-.17–.17
Meyer, J. (1997; Exp. 2a)	29	Money	—	65.57	Not considered	Stroop	-.17	-.50–.17
Meyer, J. (1997; Exp. 2b)	11	Money	—	70.49	Not considered	Stroop	-.33	-.59–.07
Meyer, J. (1997; Exp. 3)	30	Money	—	92.67	Not considered	Stroop	.17	-.08–.42
Meyer, M. (2012; Exp. 2)	58	Smiling face	67.89	45.11	Not considered	Stroop	.15	-.03–.33
Meyer, M. (2012; Exp. 3)	63	Smiling face	67.89	45.11	Not considered	Other	.00	-.17–.17
Miller (1998)	36	General mixed	90.00	72.22	Not considered	Stroop	.00	-.23–.23
Mogg et al. (1998; High-hunger)	15	Food	—	—	Considered	DPDT	.14	-.11–.38
Mogg et al. (1998; Low-hunger)	15	Food	—	—	Not considered	DPDT	-.17	-.46–.12
Mogg & Bradley (1999a; Exp. 1)	32	Smiling face	—	—	Not considered	DPDT	.37	.00–.73
Mogg & Bradley (1999a; Exp. 3)	23	Smiling face	—	—	Not considered	DPDT	.03	-.30–.37
Mogg & Bradley (1999b; Exp. 2)	20	Smiling face	—	—	Not considered	DPDT	.43	.10–.76
Mohanty et al. (2008)	7	Food	80.00	—	Considered	Other	.37	-.13–.86
Most et al. (2007; Exp. 1)	20	Erotic/attractive	78.89	67.78	Considered	RSVP	.93	.51–1.34
Most et al. (2007; Exp. 2)	20	Erotic/attractive	78.89	67.78	Considered	RSVP	.65	.29–1.00
Most et al. (2007; Exp. 3)	16	Erotic/attractive	75.56	75.56	Not considered	RSVP	.66	.30–1.02
Newman (2011)	58	General mixed	—	—	Not considered	Free viewing	1.03	.77–1.29
Noeker (2006; Exp. 2; Older adults)	14	General mixed	83.33	65.56	Not considered	Other	.00	-.30–.30
Noeker (2006; Exp. 2; Younger adults)	18	General mixed	82.44	55.56	Not considered	Other	.00	-.33–.33
Nummenmaa et al. (2006; Exp. 1)	23	Baby/child	83.67	56.78	Not considered	Free viewing	.64	.30–.97
Nummenmaa et al. (2006; Exp. 2)	32	Baby/child	83.67	56.78	Not considered	Free viewing	.37	.12–.63
Nummenmaa et al. (2009; Exp. 1)	30	Erotic/attractive	80.00	60.56	Not considered	Visual search	.26	.00–.51
Nummenmaa et al. (2009; Exp. 2)	30	Erotic/attractive	80.00	60.56	Not considered	Visual search	.60	.31–.89
Nummenmaa et al. (2009; Exp. 3)	15	Erotic/attractive	80.00	60.56	Not considered	Visual search	.96	.38–1.54
Nummenmaa et al. (2011; Exp. 1)	27	Food	73.78	—	Not considered	Visual search	.44	.15–.72
Nummenmaa et al. (2011; Exp. 2)	18	Food	73.78	—	Not considered	Visual search	-.09	-.35–.17
Oehlberg (2013)	110	Erotic/attractive	82.33	51.00	Not considered	Free viewing	.11	-.02–.24
Owens (2013; Exp. 1)	33	General mixed	—	—	Not considered	Stroop	.06	-.17–.30

(Appendix continues)



## Appendix (continued)

Study	<i>n</i>	Stimulus	Valence	Arousal	Relevance	Paradigm	<i>g</i>	95% CI
Paelecke et al. (2012)	112	General mixed	62.40	—	Not considered	Stroop	-.28	-.41-.14
Petropoulos (2012)	178	General mixed	80.00	61.00	Not considered	Stroop	.00	-.10-.10
Piech et al. (2010)	23	Food	67.00	70.00	Considered	RSVP	.33	.03-.62
Pool (2011)	49	General mixed	83.56	59.22	Not considered	DPDT	.00	-.19-.19
Pool (2013)	21	Food	70.00	—	Considered	SCT	.38	.07-.69
Pool et al. (2014; Exp. 1)	18	Food	—	—	Considered	SCT	.43	.09-.77
Pool et al. (2014; Exp. 2: Control)	16	Food	51.00	—	Considered	SCT	-.09	-.39-.22
Pool et al. (2014; Exp. 2: Sated)	19	Food	69.00	—	Not considered	SCT	.52	.14-.89
Pourtois et al. (2004; Behavioral Exp.)	16	Smiling face	59.94	29.31	Not considered	DPDT	.14	-.19-.47
Pourtois et al. (2004; EEG Exp.)	12	Smiling face	59.94	29.31	Not considered	DPDT	.00	-.37-.37
Prause (2007)	66	Erotic/attractive	72.00	74.06	Not considered	DPDT	-.36	-.54-.18
Prause et al., (2008)	69	Erotic/attractive	62.78	57.22	Not considered	DPDT	-.71	-.50-.91
Raymond & O'Brien (2009; Exp. 2)	17	Money	—	—	Not considered	RSVP	.00	-.32-.32
Rozak (1993)	88	General mixed	—	—	Considered	Stroop	.22	.07-.37
Rusting (1997; Exp. 1)	149	General mixed	86.00	—	Not considered	DPDT	.21	.09-.32
Rutherford et al. (2010)	38	Money	—	—	Not considered	SCT	-.18	-.40-.04
Sass (2010)	122	General mixed	—	—	Not considered	Stroop	.35	.22-.49
Sato & Yoshikawa (2010; Exp. 1a)	17	Smiling face	59.94	29.31	Not considered	Visual search	.63	.19-1.01
Sato & Yoshikawa. (2009; Exp. 1b)	17	Smiling face	59.94	29.31	Not considered	Visual search	1.14	.25-1.64
Schimmack & Derryberry (2005; Exp. 1)	126	Erotic/attractive	67.63	73.75	Considered	Other	.36	.23-.49
Schimmack & Derryberry (2005; Exp. 2)	60	Erotic/attractive	67.63	73.75	Considered	Other	.35	.16-.53
Segerstrom (2001)	48	General mixed	85.71	—	Not considered	Stroop	.28	.08-.49
Shapiro et al. (1997; Exp. 1)	27	Self relevant	—	—	Considered	RSVP	.52	.23-.81
Shelley-Tremblay & Mack (1999; Exp. 1)	11	Smiling face	—	—	Not considered	Other	.62	.16-1.09
Shelley-Tremblay & Mack (1999; Exp. 2)	10	Self relevant	—	—	Considered	Other	.64	.15-1.13
Shelley-Tremblay et al. (1999; Exp. 3)	10	Self relevant	—	—	Considered	Other	.59	.11-1.07
Singh (2011)	86	Smiling face	67.89	45.11	Not considered	Free viewing	.14	-.01-.29
Stasio (2011; Exp. 2)	249	Erotic/attractive	—	—	Not considered	DPDT	.00	-.09-.09
Steinmetz et al., (2010)	47	General mixed	83.22	68.22	Not considered	RSVP	.34	.13-.55
Stormark & Torkildsen (2004)	24	Food	—	—	Not considered	Stroop	.00	-.27-.27
Strauss (2004)	30	General mixed	—	95.14	Not considered	Stroop	.48	.20-.75
Sutton (2010; Exp. 2a)	64	General mixed	70.91	55.64	Not considered	DPDT	.00	-.17-.17
Sutton (2010; Exp. 2b)	64	General mixed	73.91	55.64	Not considered	DPDT	.15	-.03-.32
Sutton & Altarriba (2011; Exp. 1)	64	General mixed	86.67	68.00	Not considered	DPDT	.03	-.14-.21
Sutton & Altarriba (2011; Exp. 2)	64	General mixed	86.67	68.00	Not considered	DPDT	.08	-.09-.25
Talmi (2006; Exp. 1.)	24	General mixed	—	—	Not considered	Other	.34	.05-.63
Talmi et al., (2007; Exp. 1)	24	General mixed	71.33	71.78	Not considered	Other	.36	.07-.65
Talmi et al. (2013; Fasted)	22	Food	—	—	Considered	Other	.56	.23-.88
Talmi et al. (2013; Sated)	21	Food	—	—	Not considered	Other	.00	-.29-.29
Tapper et al. (2010)	89	Food	—	—	Not considered	DPDT	.21	.06-.36
Theeuwes & Belopolsky (2012)	16	Money	—	—	Not considered	Visual search	.42	.06-.78
Tipples & Sharma (2000; Exp. 1)	28	General mixed	79.56	64.44	Not considered	Other	.32	.05-.59
Tipples et al. (2002; Exp. 2)	12	General mixed	85.22	48.33	Not considered	Visual search	.45	.04-.86
Tipples et al. (2002; Exp. 3)	15	General mixed	85.22	48.33	Not considered	Visual search	.00	-.34-.34
Tipples et al. (2002; Exp. 5)	16	General mixed	—	—	Not considered	Visual search	.57	.19-.96
Tipples (2006)	38	Smiling face	59.94	29.31	Not considered	Other	.00	-.22-.22
van Hooff et al. (2011)	40	Erotic/attractive	65.00	—	Considered	Other	.29	.13-.46
Wang et al. (2013; Exp. 1)	24	Money	—	—	Not considered	Visual search	.61	.29-.93
Wang et al. (2013; Exp. 2a)	24	Money	—	—	Not considered	Visual search	.65	.32-.98
Wang et al. (2013; Exp. 2b)	24	Money	—	—	Not considered	Visual search	.00	-.27-.27
Wang et al. (2013; Exp. 2c)	24	Money	—	—	Not considered	Visual search	.00	-.27-.27
Waters et al. (2007)	13	General mixed	80.11	66.89	Not considered	SCT	.06	-.31-.42
Williams et al. (2005; Exp. 1)	12	Smiling face	—	—	Not considered	Visual search	1.80	.99-2.61
Wright (1995; Heterosexual men)	20	Erotic/attractive	—	—	Considered	Other	.87	.47-1.27
Wright (1995; Heterosexual women)	20	Erotic/attractive	—	—	Considered	Other	.60	.25-.95
Wright (1995; Gay men)	20	Erotic/attractive	—	—	Considered	Other	.92	.50-1.33
Wright (1995; Gay women)	20	Erotic/attractive	—	—	Considered	Other	.86	.46-1.26
Yamada et al. (2012)	15	Self relevant	—	—	Considered	Other	.42	.05-.80

Note. *g* = Hedges' *g*, which is the standardized difference between the neutral and the positive emotion condition; CI = confidence interval; DPDT = dot probe detection task; SCT = spatial cuing task; RSVP = rapid stream visual presentation; Exp. = experiment.

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