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Blushing and Social Anxiety: A Meta-Analysis

According to Darwin, (1872, p. 310) blushing is “the most human of all expressions” as it does not exist among animals. Although blushing is a common and universal phenomenon (Leary & Meadows, 1991), it can also be a symptom of psychopathology (Stein & Bouwer, 1997). Blushing was recently introduced in DSM-5 as a specific physiological component of social anxiety disorder (SAD) (APA, 2013, p. 204). Because it has been hypothesized that blushing may occur when people are concerned with others’ evaluative views of themselves (Buss, 1980; Edelmann, 1990; Leary & Meadows, 1991), people who are more concerned about others’ evaluation could be particularly prone to blushing (Voncken & Bögels, 2009). As fear of negative evaluation is the core feature of SAD, and fear of showing bodily symptoms such as blushing is one of the fears of those suffering from SAD (Bögels & Voncken, 2008), people who are highly socially anxious may be most prone to blushing. Therefore, vulnerability for more frequent or more intense blushing may be one of the etiological markers of the development of SAD (Voncken & Bögels, 2009).

Furthermore, there is a group of people with SAD for whom blushing may be so embarrassing that it evokes fear and avoidance of social situations (Bögels, 2006; Bögels et al., 2010). For this group of individuals, blushing might not only be a symptom of SAD, but also become a source of fear itself and help to maintain SAD (Bögels, 2006). A cognitive model of fear of blushing has been proposed to account for the role of blushing in the maintenance of SAD (Dijk, Voncken, & de Jong, 2009). According to this model, socially anxious individuals with a specific fear of blushing are characterized by a belief that they are blushing in a socially fearful situation (no matter their actual blushing) which gives rise to dysfunctional and negative thoughts and beliefs regarding costs of blushing (e.g., expectations that one will be rejected by

others because of their blushing). These negative thoughts cause fear, which, in turn, further render the vicious circle and help to maintain social anxiety through avoidance of socially fearful situations. Thus, blushing may not only be a symptom of SAD, but also a factor in its maintenance.

Although blushing is recognized as an important problem in SAD, its relation to social anxiety is not yet fully understood. Previous research in the field has investigated the role of blushing in SAD, but studies have yielded inconsistent findings. Therefore, the extent to and the way in which blushing is related to social anxiety is still unclear. In the present meta-analysis, we focus on blushing, its association with social anxiety, and factors that may influence this association.

Phenomenology of Blushing

Blushing is defined as an uncontrollable reddening of the face, neck, and/or upper chest that people experience in reaction to real or perceived evaluation or social attention (Leary & Toner, 2012). Blushing seems to occur with various emotions that share one universal element – a feeling of self-consciousness (Crozier, 2004; Crozier & Russell, 1992; Leary, Britt, Cutlip, & Templeton, 1992). It is assumed to be “a hallmark” of embarrassment (Buss, 1980). Previous studies (Edelmann, 1990; Parrott & Smith, 1991) revealed that the majority of respondents reported blushing as occurring during a specific embarrassing situation, and almost all respondents assumed that blushing was a typical feature of embarrassment in retrospective reports. However, as noted by Leary et al. (1992), blushing is not a unique signal of embarrassment. It is not tied to any specific emotion and can accompany a range of self-consciousness emotions such as shame, guilt, embarrassment, shyness, and pride.

It has been assumed that blushing is a signal indicative of a high level of ambivalent arousal (van Hooff, 2012). The individual experiences an urge to flee and, at the same time, needs to inhibit such a tendency, as a flight may have social consequences (de Jong & Dijk, 2012). It signals that the individual is subject to an acute concern and experiences acute self-awareness (de Jong & Dijk, 2012).

Blushing and Social Anxiety

Blushing is often associated with social anxiety disorder (SAD) (Stein & Bouwer, 1997), since it is thought that SAD has at its core the fear of being negatively evaluated by other people (Bögels & Voncken, 2008; Bögels et al., 2010). Past research in the field only partly supports the hypothesis that blushing is related to social anxiety. Conflicting results can arise from various operationalizations of blushing and social anxiety. The relationship between blushing and social anxiety may partly depend on the social anxiety type (e.g., generalized social anxiety, interaction anxiety, specific fear of blushing). Inconsistent results regarding the association between blushing and social anxiety may also partly arise due to the way in which blushing is measured (e.g., self-perceived, physiological, or observed blushing).

The hypothesis that the strength of the relationship between blushing and social anxiety may depend on the way in which blushing is measured may have important implications regarding cognitive models of social anxiety. The integrated cognitive-behavioral model of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997) proposes that socially anxious individuals use internal cues as a source of information when making judgments regarding the possibility of negative evaluation. The individuals attend to their own internal impression of themselves which is influenced by autonomic symptoms of anxiety (particularly those that might

be visible, such as blushing), and assume that this is how others see them (Schultz & Heimberg, 2008).

If, indeed, social anxiety is strongly related to self-perceived blushing, whilst the relation with actual blushing is not high, it may be hypothesized that socially anxious individuals use not only interoceptive cues, but also other types of information to create an impression about themselves. It is also possible that cognitive processes play an important role in the perception of interoceptive information in socially anxious individuals, leading them to create a biased impression of themselves.

Self-perceived Blushing and its Relation to Social Anxiety.

Self-perceived blushing is defined as the extent and frequency to which individuals report that they blush in everyday situations. Self-perceived blushing is found to be strongly associated with social anxiety and to a range of self-report measures assumed to be correlated with social anxiety, such as embarrassibility, attention to social comparisons, self-consciousness, shyness and anxiety sensitivity (e.g., Edelmann, 1990; Leary & Meadows, 1991; Neto, 1996). However, smaller correlations were reported in a few studies (Bögels, Alberts & de Jong, 1996; Bögels & Voncken, 2008) when a one-item measure of blushing frequency was used. Although the majority of the studies show that socially anxious people perceive themselves as blushing more than less socially anxious people, different studies have reported different effect sizes.

Physiological Indices of Blushing and Their Relation to Social Anxiety.

The physiological mechanism underlying the blushing response has not been fully clarified yet, but it has been suggested that it is a sympathetically-driven response resulting in vasodilatation of the vessels in the face and neck (Drummond, 1997). Specifically, blushing

involves an accumulation of red blood cells in the superficial venous plexus of the facial skin due to sympathetically-mediated dilatation of the arterial supply (Drummond, 1997, 2012).

Although the mechanism underlying blushing has not been clarified fully, physiological blushing is a commonly used measure in the studies of the association between blushing and anxiety. Temperature and/or blood flow of the cheeks and/or forehead are used as indicators of blush response. Physiological blushing is typically measured in socially fearful situations (e.g., a performance situation or interaction with strangers). A few studies that used measures of physiological blushing (e.g., Drummond et al., 2007; Mulkens, de Jong, & Bögels, 1997) failed to find the relationship between physiological parameters of blushing and social anxiety. In contrast, other studies (e.g., Bögels, Rijsemus, & De Jong, 2002; Drummond & Lazaroo, 2012) supported the hypothesis that physiological blushing is related to social anxiety.

Observed Blushing and its Relation to Social Anxiety.

To our knowledge, only three studies (Bögels et al., 2002; Gerlach, Wilhelm, Gruber, & Roth, 2001; Voncken & Bögels, 2009) have investigated blushing observed by other people in relation to social anxiety. Although there is initial support for the hypothesis that blushing rated by others is more common or intense in socially anxious people than those who are not socially anxious, evidence is still scarce.

Moderators of the Relationship Between Blushing and Social Anxiety

The lack of consistency in the literature investigating blushing and social anxiety might also reflect the fact that not all socially anxious people blush more than those who are not socially anxious. There might also be large variability within the group of socially anxious individuals (referred to as SAD patients or high socially anxious people) with respect to blushing propensity, frequency, intensity, and visibility (Voncken & Bögels, 2009).

Social Anxiety Measures.

Social anxiety may be operationalized in various ways. These variations may influence the strength of the relationship between blushing and social anxiety. Some studies defined social anxiety as a disorder (e.g., Bögels, 2006; Bögels & Voncken, 2008) while other studies defined it on a trait or state continuum (e.g., Muller-Pinzler, Paulus, Stemmler, & Krach, 2012).

Studies that investigate blushing and social anxiety may measure more specific fear (e.g., fear of blushing) (e.g., Bögels & Lamers, 2002) or less specific fear (e.g., fear of negative evaluation) (e.g., Chen & Drummond, 2008). Furthermore, social fear can be defined as a state and measured with self-rating embarrassment scales on which participants rate their embarrassment after an experimental task. (e.g., Drummond, 2001). The way in which social fear is measured can be expected to moderate the association between blushing and social anxiety. Specific fear of blushing may be expected to have a stronger association with blushing than a less specific social fear. Furthermore, a state of embarrassment may be expected to be more related to blushing than social anxiety defined as a trait, as it is measured in the same settings and at the same time as blushing – during an embarrassment- inducing situation.

Blushing Measures.

Both self-perceived and physiological blushing may be measured in various ways (e.g., various questionnaires, blood flow or temperature). Different properties of these measures (e.g., psychometric properties of a questionnaire, artifacts associated with physiological measures) might influence the strength of the relationship between blushing and social anxiety.

The Present Study

Although blushing is a very common emotional response and a characteristic of normal human functioning (Leary et al., 1992), some people report that they blush more frequently

and/or readily than others (Leary & Meadows, 1991). Blushing may be a symptom of psychopathology in SAD, and a source of fear for a group of socially anxious individuals who are particularly concerned about their bodily symptoms (Bogels, Mulkens, & de Jong, 1997). As such, a role of blushing in social anxiety has been investigated in past studies. Because of the mixed findings reported in these studies, it is not yet fully understood how and to what extent blushing is related to social anxiety. Therefore, a meta-analysis on the relationship between blushing and social anxiety was conducted on the existing literature.

The purpose of the meta-analysis was to address two key questions that would assist in clarifying current knowledge on the role of blushing in social anxiety: (a) estimation of the association between social anxiety and self-perceived, observed, and physiological signs of blushing, and (b) investigation of moderators that might influence these associations. Moderator analyses were performed to account for factors that might influence the relationship between blushing and social anxiety (social anxiety type, country, clinical status of a sample) and to control for sample characteristics (age, gender), and study quality (study design, and tasks used).

Method

Identification and Selection of Studies

We conducted systematic searches for studies presenting quantitative data on the association between blushing and anxiety, published through June, 2013 using ISI Web of Knowledge, PsycINFO, ERIC, and PubMed. We searched for studies using combinations of the keywords blush* and anx*, internaliz*, fear*, obsessive, compulsive, OCD, panic, phobi*, worr*, inhibit*, shy*, somat*, embarrass*. We supplemented our searches by looking for potentially relevant articles in Google Scholar. In addition, we hand-searched reference sections

of all relevant empirical and review articles, and contacted authors in the field to obtain information about unpublished studies. Figure A.1 shows the flow chart of the selection process.

The following inclusion criteria were used in the study selection process: (a) use of a measure of frequency and/or intensity of blushing (e.g., questionnaire), (b) use of a social anxiety measure (e.g., clinical interview), (c) sufficient data were provided (reported in the text or provided by the authors) to calculate an effect size between blushing and social anxiety. More specifically with regard to (c), studies were included if they reported at least one association between blushing and anxiety regardless of the specific aims of the study. For example, we included studies that focused on the treatment of socially anxious patients as long as they provided pretreatment data for the association between blushing and social anxiety. In terms of population, studies recruiting healthy adults and children from various demographic groups (e.g., undergraduate students), as well as participants selected on the basis of anxiety disorder diagnosis (e.g., clinical patients with diagnosis of social anxiety disorder) or other anxiety-related measures (e.g., low or high trait anxiety) were included in the analyses.

We excluded studies in which blushing was defined only in terms of cognitions regarding blushing (e.g., concerns or biases regarding blushing) or fear of blushing (e.g., Dijk, de Jong, Müller, & Boersma, 2010). Studies that measured frequency or intensity of flushing related to non-social stressors (e.g. reddening of the cheeks during exercising) were also excluded (e.g., Bouwer & Stein, 1998), since flushing is seen as a fundamentally different response than blushing (Drummond, 2012). Studies with rosacea sufferers were excluded from the analyses (e.g., Su & Drummond, 2012), since their primary complaint is facial flushing. We also excluded studies which included participants with a medical condition (e.g., a lesion in the sympathetic pathway) (e.g., Drummond, 1989). In these cases, healthy control groups were included.

Applying these inclusion and exclusion criteria resulted in 45 studies being retained. When a study did not report data in a form that we could use or a study did not report sufficient data to calculate all the possible effect sizes, the authors were contacted and additional data were requested. Consequently, 20 authors were contacted and data were requested for 31 studies. Sixteen authors provided data for 27 studies. If data necessary to calculate an effect size were not received ($k = 4$), all the available calculable effect sizes were included in the analysis ($k = 3$). One study was excluded based solely on the missing data. This process resulted in the inclusion of 44 studies which provided a total of 69 effect sizes. Fourteen studies (16 effect sizes) provided mean difference data and thirty studies (34 effect sizes) provided correlations. Table A.1 provides descriptive information for each study included in the meta-analyses.

The meta-analysis of the association between self-perceived blushing and social anxiety included 42 studies, 44 effect sizes and 4420 participants. Twenty two studies which included 22 effect sizes and 1104 participants were included in the meta-analysis of physiological blushing and social anxiety, and three studies which included three effect sizes and 171 participants were included in the meta-analysis of the relationship between observed blushing and social anxiety.

Coding Procedures

In order to meet the statistical assumption of independence of effect sizes in each of the three meta-analyses, each study contributed only one effect size to the analysis (Lipsey & Wilson, 2001). In studies that included multiple treatment groups (e.g., socially anxious with fear of blushing and socially anxious without fear of blushing) in addition to a control group, a weighted mean of the treatment groups' scores was computed. When a study assessed blushing and social anxiety before and after an experimental between-subject manipulation or treatment (e.g., false feedback), which might influence the strength of the blushing – anxiety relationship,

the effect size was calculated using scores obtained in the baseline (pretreatment) phase. When there was no available baseline information, we included only the results of control groups. When a study with a within-subject design employed a blushing-inducing task (e.g., singing task), the effect size was calculated using scores obtained in the baseline and the task phase. When a study with a within-subject design assessed blushing and social anxiety before and after a manipulation which was not blushing-inducing, but could influence the strength of the blushing – anxiety relationship (e.g., treatment), the effect size was calculated using scores only in the pretreatment phase.

If a study was missing the necessary data to calculate effect sizes for all the measures employed in the study, but at least one effect size could be calculated on the basis of the study or additional data provided on request by the authors of the study, the average of all calculable effect sizes was used. Sensitivity analyses were computed to assess for any potential biasing effect of missing data on the effect size estimate. For two sets of effect sizes, an adjusted effect size was computed by imputing an effect size of $r = .00$ for all insignificant effect sizes that were excluded from the analyses because of missing data.

A standardized coding system was applied to every study. To assess inter-rater reliability, all studies were double coded by the first author (98% of the studies) and the second (34%), third (41%) or fifth author (25%). Reliability for the effect sizes was calculated using cross-correlation coefficients. Inter-coder agreement ranged from .90 to 1.00, indicating a high level of agreement. Rater disagreements were solved by re-assessing the study and a 100% consensus was reached.

Coding of Studies

The association between blushing and social anxiety was expressed both in terms of correlation and mean difference between groups. Because the coded studies provided effect sizes

of the r and d families, we put them in the same metric for the purpose of our analyses. We used the Pearson's product-moment correlation (r), given that r 's are more easily interpreted (Rosenthal & DiMatteo, 2001). Once all the effect sizes were expressed as correlations, they were subjected to Fisher's r -to- z transformation. Finally, the mean weighted effect sizes were returned to Pearson correlations using a z -to- r transformation for ease of interpretation. Cohen's guidelines (1988) were used for interpreting the effect sizes: effect sizes below $r = .10$ were considered to be small, around $r = .25$ to be medium, and around $r = .40$ to be large.

Moderator Analyses

To examine whether variables hypothesized to be systematically associated with effect sizes moderated the association between blushing and social anxiety, and to control for sample characteristics and quality of studies, we coded the following variables in each included study:

Characteristics of the Sample.

The mean age, percentage of males, country of participants, and clinical status of the sample were coded. A country in which the study was conducted was coded as from (a) Europe ($k = 22$); (b) North America ($k = 8$); and (c) Australia ($k = 11$). One study was conducted in Asia, but was not included in this moderation analysis. The studies were also classified based on the clinical status of the sample into one of four categories: (a) healthy sample ($k = 21$); (b) clinical sample ($k = 7$); (c) mixed sample ($k = 9$), if the sample included both the healthy and clinical subjects; and (d) selected sample ($k = 9$), if the sample was drawn from a community sample and extreme groups were selected from that sample.

Social Anxiety and Blushing Measures.

Studies were coded as defining social anxiety as (a) a continuous or (b) categorical variable. Social anxiety was coded as a continuous variable if it was measured with a

questionnaire that provided a total score on social anxiety trait or state ($k = 29$), and as a categorical variable if social anxiety was defined as a disorder ($k = 17$).

We also examined social fear type. Originally, we planned to include any type of anxiety (e.g., generalized anxiety, social anxiety); however, studies employed in the analyses utilized only measures of social anxiety or embarrassment. We therefore decided to classify measures as: (a) generalized social anxiety, (b) specific fear of blushing, (c) two or more measures of social anxiety, and (d) embarrassment measures. Twenty-two studies measured generalized social anxiety (e.g., with the Social Phobia and Anxiety Inventory; Turner, Beidel, & Dancu, 1996), five studies measured specific fear of blushing with the fear of blushing subscale of the Blushing, Sweating and Trembling Questionnaire (BTS-Q; Bögels & Reith, 1999), fourteen studies employed two or more types of social anxiety measure, and five studies measured embarrassment with self-rating scales of a state embarrassment during the task. Social anxiety was measured by: (a) questionnaire ($k = 36$), (b) clinical interview ($k = 8$), (c) or both ($k = 2$).

Self-perceived blushing was most often measured with the BPS (Leary & Meadows, 1991), or the bodily symptoms subscale of the BTS-Q (Bögels & Reith, 1999). Additionally, blushing was measured on the Visual Analogue Scale. Some studies also employed other measures of self-reported blushing (e.g. questions about frequency of blushing) and included two or more measures of blushing. We coded self-perceived blushing measures as including: (a) 10 or more items ($k = 30$), (b) five to nine items ($k = 8$), and (c) less than five items ($k = 8$).

For the association between physiological blushing and anxiety, additional moderators were coded. Physiological measures of blushing were classified as: (a) blood volume ($k = 4$), (b) temperature ($k = 2$), (c) blood flow (pulse amplitude) ($k = 13$), and (d) two or more physiological measures ($k = 3$). We also coded whether the measure was (a) in absolute values ($k = 3$), (b) in

relative values ($k = 18$), or (c) both ($k = 1$); and whether physiological blushing was measured from (a) the cheeks ($k = 11$), (b) forehead ($k = 9$), or (c) both ($k = 2$).

Study design.

A study task (performance task, interaction task, two or more tasks, other task) and a study design were coded to control for study quality characteristics. The studies included various tasks, but the most common included a performance task (e.g. singing in front of an audience) ($k = 8$), interaction task (e.g. conversation with confederates) ($k = 3$), or both ($k = 10$). Five studies employed other tasks (e.g., stories that should induce embarrassment), and 20 studies did not include any kind of embarrassing task. Studies were also coded as having a between-subjects ($k = 18$) or within-subjects design ($k = 26$).

The relationship between effect sizes and potential moderators was first explored with a series of single meta-regression analyses. For the analyses of categorical moderators, each level of a moderator had to have been measured in at least two studies to be included in the analysis. The moderators with a significant relationship to effect sizes were then included in multiple meta-regressions. All the analyses were conducted in R: A language and environment for statistical computing (R Development Core Team, 2008).

Analyses

We assumed that the effect sizes included in the meta-analyses were sampled from a universe of possible effect sizes, and as such we made unconditional inferences in order to be able to generalize beyond the observed studies (Hedges & Vevea, 1998). To be able to model these unconditional inferences, we ran random-effect models.

We used median and the median absolute deviation method to detect outliers. Final effect sizes ≥ 3 median absolute deviation (MAD) above or below the median of weighted effect size estimates were identified as outliers.

To test for homogeneity of effect sizes, the Q statistic (Hedges & Olkin, 1985) and I^2 statistic (Higgins & Thompson, 2002) were used. A significant Q statistic suggests that the distribution of effect sizes around the mean is greater than would be predicted from sampling error alone (Hedges & Olkin, 1985), and thus implies heterogeneity of effect sizes. The I^2 statistic quantifies the degree of heterogeneity by estimating the percentage of the variance that is due to between-studies variability, with percentages of $I^2 = 25, 50,$ and 75 indicating low, moderate and high degrees of heterogeneity, respectively (Higgins & Thompson, 2002). Because the studies included in the meta-analyses varied somewhat in terms of participants, design, and procedures, heterogeneity between studies was expected.

Publication Bias

Estimates of effect sizes in meta-analyses may be inflated by the fact that studies with small effect sizes or non-significant results are less likely to be published. The risk was reduced by searching and including unpublished thesis data, by requesting unpublished studies from authors who frequently publish in the field, and by requesting additional information in order to compute effect sizes for variables that were not reported in the published articles.

Publication bias was assessed in two ways. First, funnel plot (Rothstein, 2008) was created and visually inspected for both data sets. Second, Duval and Tweedie's (2000) trim-and-fill method was applied.

Results

Meta-Analyses of the Relationship Between Self-Perceived, Physiological, and Observed Blushing and Social Anxiety

The meta-analysis of effect sizes on the relationship between self-perceived blushing and social anxiety yielded a large and significant overall effect size of $r = .48$, (95% CI = [.40, .54], $k = 44$) indicating a strong, and positive relation between self-perceived blushing and social anxiety. Next, we used the “trim and fill” method (Duval & Tweedie, 2000) to calculate the effect of potential publication bias on the outcomes of the meta-analysis. The funnel plot was symmetrical (Figure A.2) and the method trimmed zero studies, indicating no evidence of publication bias. These findings supported a large and robust effect size in this data set.

A small but significant effect size was found in the meta-analysis of the association between physiological blushing and social anxiety, $r = .10$ (95% CI = [.04, .16], $k = 22$), indicating a small and positive relationship between physiological blushing and social anxiety. Inspection of the funnel plot for this set of effect sizes indicated a possible bias (Figure 2b), which was further investigated using the trim and fill method. We found that zero effect sizes were added below the estimated average effect size. However, two studies were added above the average effect size, resulting in an adjusted effect size slightly larger than the initial one ($r = .12$; 95% CI = [.05, .18]). Although the data may contain a slight bias to underestimate the effect size, it is important to note that the data set does not contain a publication bias by failing to include null effect sizes.

An overall effect size in the meta-analysis on the relationship between observed blushing and social anxiety was medium and significant ($r = .33$; 95% CI = [.13, .51], $k = 3$). The effect size indicated a moderate and positive association between observed blushing and social anxiety. The funnel plot for this set of data was symmetric (Figure 2c) and the trim and fill method

trimmed zero studies, suggesting a lack of publication bias in the data. This finding should be interpreted with caution, however, because the results are based on a small set of studies.

There was no outlying effect identified in any of the sets of the effect sizes, based on the ± 3 MAD criterion. When sensitivity analysis was conducted by imputing an effect size of $r = .00$ for one missing and non-significant effect size in the set of self-perceived blushing and social anxiety studies, and in the set of physiological blushing and social anxiety studies, the effect sizes remained significant.

Moderator Analyses

There was significant heterogeneity only in the effect sizes of self-perceived blushing and social anxiety, $Q_{(43)} = 354.66, p < .001$, much of which may be explained by between-study differences ($I^2 = 88.63$). Therefore, possible moderators were examined by running mixed models. We performed single mixed models analyses with continuous and categorical moderators. For each level of each significant categorical moderator, we report the relation between self-perceived blushing and social anxiety. Last, we report the results of a multiple regression model with all the significant moderators predicting the effect size. Table 1 provides significant results for the moderator analyses.

Sample type significantly moderated the relationship between self-perceived blushing and social anxiety ($Q_{(3)} = 12.11, p = .007$) with studies including clinical participants showing smaller effect sizes ($r = .23$; 95% CI $[-.11, .54]$, $k = 7$) than studies including only non-clinical (normal) participants ($r = .47$; 95% CI $[.36, .56]$, $k = 20$), mixed sample ($r = .40$; 95% CI $[.22, .74]$, $k = 8$), and selected sample studies ($r = .62$; 95% CI $[.35, .80]$, $k = 9$). The type of social anxiety was found to significantly influence the relationship between self-perceived blushing and social anxiety ($Q_{(3)} = 11.24, p = .011$). The moderator effect indicated that effect sizes were

larger when studies included state embarrassment ($r = .76$; 95% CI [.49, .90], $k = 4$) than effect sizes of studies that measured trait generalized social anxiety ($r = .40$; 95% CI [.29, .51], $k = 19$), trait fear of blushing ($r = .46$; 95% CI [.10, .72], $k = 6$), and two or more types of social anxiety traits ($r = .48$; 95% CI [.19, .69], $k = 15$). The number of items used to measure blushing showed a non-significant trend toward moderating the self-perceived blushing and social anxiety relationship ($Q_{(2)} = 5.61$, $p = .060$). Studies that used blushing measures with less than five items showed significantly smaller effect sizes ($r = .33$; 95% CI [-.01, .60], $k = 8$) than studies that used 10 or more items to form blushing measures ($r = .54$; 95% CI [.45, .61], $k = 28$), or blushing measures with five to nine items ($r = .40$; 95% CI [.08, .58], $k = 8$). All the differences remained significant after imputing $r = .00$ for one missing and non-significant effect size.

The type of blushing measure (propensity, frequency, or ratings of blushing) did not significantly moderate the relationship between self-perceived blushing and social anxiety. Studies that defined social anxiety as a continuous measure did not differ significantly in effect sizes from the studies that defined social anxiety as a categorical measure. Mean age, percentage of male participants, country of participants, the task and study design were also found to be non-significant moderators of the relationship between self-perceived blushing and social anxiety. These potential moderators remained non-significant after sensitivity analyses.

Multiple Regression Model.

A multiple meta-regression analysis was conducted with effect sizes as the dependent variable and sample type, number of items included in the measure of self-perceived blushing and type of social anxiety as predictors, to account for possible overlapping effect between the significant moderators. Table 2 reports the results of the multiple regression model. The model explained 38% of the variance in the effect size. Supporting earlier analyses, the effect size was

stronger for the studies that measured embarrassment, compared to other social anxiety types ($\beta = .75, p = .004$). Importantly, after controlling for other moderators, studies with clinical samples did not differ significantly in the effect size from studies with normal, mixed, or selected samples. Furthermore, studies with less than five items for a blushing measure had a significantly lower effect size than studies that employed blushing measures with five to nine items, or more than 10 items ($\beta = .27, p = .050$).

Meta-Analysis of the Relationship Between Self-Perceived and Physiological Blushing

Because the effect size of the relationship between blushing and social anxiety depended on the blushing measurement technology (large effect for self-perceived blushing, and small effect for physiological blushing), an additional meta-analysis on the relationship between self-perceived blushing and physiological blushing was computed on available data from the studies included in the previous meta-analyses. A small and significant effect size was found, $r = .18$, (95% CI = [.10, .25], $k = 13$) suggesting a small, positive relationship between self-perceived and physiological blushing.

Discussion

The Relationship Between Blushing and Social Anxiety

In this meta-analysis we examined the relationship between three measures of blushing (self-perceived, physiological, and observed) and social anxiety. Because the meta-analysis on the association between observed blushing and social anxiety was based only on three studies, the results of this study were not directly compared to the results of two other meta-analyses. It was hypothesized that two measures of blushing (self-perceived and physiological) would be positively associated with social anxiety, and that individual factors (e.g., social anxiety

measures and blushing measures) would moderate these associations. In addition, the relationship between self-perceived blushing and physiological blushing was examined.

The main findings of the meta-analyses were that: (a) Two measures of blushing were positively associated with social anxiety: the association with self-perceived blushing was strong ($r = .48$), and with physiological blushing small ($r = .10$); (b) Low convergence between self-perceived blushing and physiological blushing was found ($r = .18$); (c) Social anxiety type and number of items within blushing questionnaires significantly moderated the relationship between self-perceived blushing and social anxiety, with studies including embarrassment showing a stronger relationship than studies including other types of social anxiety, and with studies that employed a blushing questionnaire, with five or less items showing a smaller relationship between self-perceived blushing and social anxiety than studies that employed blushing questionnaires with six or more items.

Main Findings.

Both measures of blushing were associated with social anxiety in the predicted direction. A strong correlation was obtained between self-perceived blushing and social anxiety, supporting the results from previous studies on self-perceived blushing: individuals who are more concerned with other's evaluations of them perceive themselves as blushing more intensely or more frequently than people who are less concerned with others' evaluations. However, the relationship between physiological blushing and social anxiety was small, indicating that, although socially anxious people perceive themselves to be blushing more than individuals who are less socially anxious, social anxiety is not strongly associated with physiological blushing.

One possible interpretation of the findings of this meta-analysis considers the cognitive model of social anxiety. Self-perceived blushing is a measure that may be influenced by the

respondent. It is likely that it represents not only blushing but also subjective experience connected to it - concerns and worries about blushing (Edelmann, 2001). Thus, respondents may overestimate their blushing and perceive themselves as blushing more than they actually do, if they are prone to concerns and worries about others' evaluations of them.

According to the cognitive model of social anxiety (Clark & Wells, 1995; Rapee & Heimberg, 1997), socially anxious individuals use interoceptive information to create an impression of how they appear to their audience. They focus on negative cognitions which are based on their physiological signals, and on external cues which they perceive as threatening (Rapee & Heimberg, 1997). They show biased appraisal of the environment during a social event and focus on threatening cues (Bögels & Mansell, 2004; Hirsch & Clark, 2004). Because socially anxious people overestimate their blushing (they assume they are blushing more than people who are less socially anxious, but the actual difference in blushing between these two groups is small), it is also possible that their assessment of physiological functioning on which they base their representation of themselves is biased.

The hypothesis that the change in physiological functioning seems to be overestimated in socially anxious people would imply that, in addition to biased assessment of the social factors, biased appraisal of interoceptive information may also contribute to social anxiety. One study (Voncken & Bögels, 2009) that compared blushing in socially anxious people and controls provides indirect support for this hypothesis: the relationship between self-perceived blushing and physiological blushing (blood flow and temperature) was higher in healthy controls than in socially anxious people, indicating that socially anxious people are less accurate than people who are not socially anxious when estimating their blushing. These findings suggest that individual differences in accuracy of estimating physiological change are stronger in socially anxious

people than healthy controls. Specifically, it might be that a subgroup of people with SAD and fear of blushing overestimate their blushing, whereas other people with SAD are more accurate when estimating their blushing. As a result, less accuracy in estimating real blushing may be found in the group of people with SAD compared to people without SAD.

The hypothesis of biased appraisal of interoceptive information which leads to overestimation of physiological change in socially anxious people is supported by a number of studies that have found that socially anxious individuals who are informed that their physiological anxiety level (e.g., heart rate) is increasing during a social situation (regardless of the veracity of this information) report greater subjective anxiety than if they are told their symptoms are diminishing (Wells & Papageorgiou, 2001). Studies with false feedback of blushing confirmed that false positive feedback increased embarrassment and subjective feelings of blushing, whereas physiological blushing was less affected by the false feedback (Dijk et al., 2009; Drummond et al., 2003). These results support the idea that the *perception or interpretation* of physiological functioning, rather than actual physiological functioning, is included in the creation of internal representations of socially anxious individuals.

Domschke, Stevens, Pfleiderer, and Gerlach (2010) gave support for the same underlying cognitive mechanisms in the case of other physiological responses. They reported on a dysfunctional cognitive appraisal of body sensations (particularly heartbeat) with a bias towards a catastrophizing interpretational style in anxious individuals, supporting the hypothesis that not only elevated physiological responding but also biased perception of these responses seems to be typical of anxiety.

It is also possible that socially anxious people are not a homogenous group, and that they differ from each other in a reaction system that is most activated in a socially fearful situation.

Öst, Jerremalm, and Johansson (1981) distinguished between “cognitive reactors” and “physiological reactors”. It may be that socially anxious people who perceive themselves as blushing when they do not actually blush are “cognitive reactors”, while people who actually blush might be “physiological reactors”. Differences in a dominant reaction system within socially anxious individuals may account for differences found in the relationship between social anxiety and self-perceived blushing, and social anxiety and physiological blushing, with “cognitive reactors” being more prevalent than “physiological reactors” in the group of socially anxious people.

The finding of the meta-analysis that self-perceived blushing was more strongly associated with social anxiety than physiological blushing may also be explained by the fact that, unlike self-perceived blushing, physiological blushing was always measured in lab settings (e.g., singing task, speech task), and in situations that may or may not adequately represent situations in which people blush in daily life. In support of this, Dijk and de Jong (2012) found that socially anxious people report not only a higher probability of displaying a blush in embarrassing situations, but also in neutral situations (in which people usually do not blush) compared to non-socially anxious people. However, physiological blushing was only assessed in settings in which embarrassment-inducing tasks were employed. Thus, it is possible that taking into account neutral situations, rather than only embarrassing situations, would better distinguish between blushing in socially anxious and non-socially anxious individuals.

It may also be that the stronger relation between self-perceived blushing and anxiety, as compared to the relation to physiological and observed blushing, was found as a result of the same measurement domain – unlike physiological blushing, self-perceived blushing and social anxiety are self-reported measures. They are both prone to the same kind of bias, (i.e.,

respondent bias). Objective measures, such as physiological data, are free from the influence of the respondent, but may be prone to other types of bias (e.g., specific measurement error). Thus, smaller correlation between physiological measures of blushing and social anxiety may be expected due to different measurement domains and specific errors connected to the domains.

Moderators.

Social fear type moderated the relationship between self-perceived blushing and social anxiety, with studies including embarrassment showing the strongest association between self-perceived blushing and social anxiety. The emotion most commonly linked with blushing is embarrassment (Edelmann & Hampson, 1981; Tangney, Miller, Flicker, & Barlow, 1996), and blushing and embarrassment are often assumed to co-occur (Edelmann, 2001). People generally believe that when one is blushing, one is embarrassed (Edelmann, 2001). Furthermore, both embarrassment and blushing are states measured at the same time point, which is not case for social anxiety. The finding that people usually expect that blushing would occur when one is embarrassed may explain why blushing is more strongly connected to embarrassment than to social anxiety measured as a trait.

After controlling for the inter-correlation between moderators, the number of items included in the blushing questionnaire became a significant moderator, with studies that employed a blushing questionnaire (or a scale) with less than five items showing the smallest relationship between self-perceived blushing and social anxiety. Questionnaires with less than five items were mostly applied in lab settings after the task employed in the study, and consisted of the self-rating scales of blushing during the task. On the other hand, questionnaires with five or more items (e.g., BPS, bodily symptoms subscale of BTS-Q) used a range of situations to assess blushing in daily situations. It might be that propensity to blush in daily life is more

relevant for the relationship between blushing and social anxiety than self-perceived blushing under particular, embarrassing circumstances, and thus, a stronger relationship is found with the questionnaires that assess blushing propensity more broadly. Moreover, when two variables are truly related, the found association will be higher when the variables possess higher reliability. Thus, increasing internal reliability by increasing the number of items of a questionnaire might also influence the relationship between the two variables in question.

Clinical Implications

The present findings may have important implications for the treatment of blushing. Concerns have been raised about bilateral endoscopic transthoracic sympathectomy which is an available surgical treatment for blushing (Dijk, & De Jong, 2006; Drummond, 2000), because there is a high chance that sympathectomy causes side effects such as compensatory sweating and pathological gustatory sweating and flushing (Drummond, 2000). The results of these meta-analyses show that self-perceived blushing is strongly associated with social anxiety, whilst the correlation between self-perceived blushing and actual blushing is small. It might be that the source of the problem for people who consider surgery is fear of blushing rather than blushing itself. In this respect, more appropriate treatment for individuals who seek treatment for blushing would be interventions that focus on social anxiety: cognitive behavior treatment or task concentration training. It is likely that by helping individuals to overcome anxiety about blushing, clinicians could help individuals to reduce unpleasant feelings associated with the anticipated consequences of blushing. It was reported that the cognitive behavior treatment outcomes are positive especially in the case of individuals with specific social fears (Hofmann, 2000).

Limitations

This study has a few limitations. First, studies investigating blushing and social anxiety have been conducted for just two decades and, as a result, some of the analyses in the present investigation were conducted based on a small number of studies. Although the meta-analyses on self-perceived blushing and social anxiety ($k=44$), and physiological blushing and social anxiety ($k=22$) were based on a moderate number of studies, the meta-analysis of observed blushing and social anxiety was based only on three studies. The finding of this meta-analysis should be interpreted with caution because the small number of effect sizes might have limited the generalizability of our findings. Second, although many of the moderators that were examined were not significant, it is possible that we did not have sufficient power to detect significant effects, as the number of studies for each level of the moderator under investigation was in some cases low. As a consequence, high heterogeneity among the studies that investigated self-perceived blushing in relation to social anxiety was not fully explained.

Regarding the studies included in this meta-analysis, it is worth mentioning that physiological blushing was always measured in the lab settings, unlike self-perceived blushing which was assessed in the lab settings and in various every-day situations. Therefore, it was not possible to measure physiological blushing response in various social situations and to generalize the findings of these studies on daily situations.

Future Directions

Because of the inconsistent pattern of the relationship between blushing and social anxiety, researchers should consider which aspect of blushing they want to measure when studying it in relation to social anxiety. It is also recommended that researchers consider which social anxiety measure should be used, as the results of this meta-analysis showed that effect sizes may differ depending on the definition of social anxiety. When conducting a study with

self-perceived blushing, psychometric properties of blushing questionnaires should also be considered, as they may influence the correlation between blushing and social anxiety.

Researchers should also carefully consider the sample. Clinical and healthy samples may differ not only in their experience of blushing and social anxiety but also possibly in physiological blushing. The studies should also be powered to examine potential differences in the blushing – social anxiety relationship between healthy samples and patients. Of special interest would be to further examine the relationship between self-perceived and physiological blushing separately in socially anxious people and controls.

It is also recommended that studies include observational measures of blushing. Blushing may now be more precisely and reliably observed with development of new technologies (e.g., Eulerian Video Magnification; Wu et al., 2012). It is possible that new information about blushing would be obtained, as there are only 3 studies so far investigating observed blushing. Researchers should also attempt to determine possible age and gender differences in blushing. Gender differences have been mostly studied in healthy samples so far, while there is a general lack of studies that considered age differences in blushing in people with SAD. Interestingly, there is no study that investigated blushing in relation to social anxiety in early adolescence, although it is thought that this is a sensitive period in life when social anxiety and blushing might be heightened (Abe & Masui, 1981; Shileds, Malory, & Simon, 1990). There is surprisingly no study that investigated physiological or observed blushing in children. Furthermore, a longitudinal study which would examine development of blushing in relation to social anxiety is needed to help clarify the etiological and maintaining features of blushing in social anxiety. Finally, the current findings point to the importance of assessing blushing in daily life. Although

this may present a challenge for measuring physiological blushing, it would be helpful to acquire data about both self-perceived and physiological blushing in every-day social situations.

Conclusion

In this study, we provide evidence for the relationship between blushing and social anxiety. The strongest association was found between self-perceived blushing and social anxiety, particularly embarrassment, and the smallest between physiological blushing and social anxiety. This implies that the more people feel embarrassed or are socially anxious, the more they have the feeling they blush, no matter their actual, physiological blushing. This result confirms the fundamental role of cognitive processes in blushing and social anxiety. The present findings contribute to the literature by suggesting that socially anxious people overestimate their blushing. However, it is still not clear how the relationship between physiological, self-perceived blushing and social anxiety functions in daily life. Therefore, blushing deserves more researchers' attention and future research on the topic is needed in order to clarify the role of blushing in social anxiety.

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