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The effect of facial blood flow on ratings of blushing and negative affect during an embarrassing task: preliminary findings

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Abstract

Expecting to blush is a common source of social anxiety, and is associated with heightened perceptions of blushing and embarrassment. To assess whether sensory cues associated with heightened facial blood flow are an additional source of anxiety, the vasodilator niacin (100 mg) or placebo was administered double-blind to 33 participants, and facial blood flow was investigated when they sang a children’s song. Vasodilatation during singing was greater in the niacin than placebo condition, and niacin-evoked flushing and increases in pulse rate were greater in participants with high than low fear of negative evaluation. Nevertheless, ratings of embarrassment, anxiety, blushing and facial heat were similar in both drug conditions. This dissociation implies that cognitive appraisals or negative affect overrode more subtle physiological cues of blushing during embarrassment. Clarifying how judgments about blushing are made could be crucial for correcting faulty assumptions about blushing in people who are frightened of this response.

Key words: facial blood flow; vasodilatation; niacin; embarrassment; social anxiety; fear of negative evaluation
1. Introduction

Blushing refers to transient reddening of the face, typically in association with feelings of embarrassment, guilt or shame elicited by scrutiny or appraisal (Shearn et al., 1990; Leary et al., 1992). Although blushing may help to remedy social transgressions (Keltner and Buswell, 1997; Keltner and Anderson, 2000; Dijk et al., 2009a), nevertheless people who are concerned about blushing inflate both the probability and costs of blushing (Dijk et al., 2010). Blushing is usually associated with discomfort and a lack of poise, and can become a major source of anxiety during social interactions (Edelmann, 2001).

Blushing usually peaks within seconds and subsides within minutes (Shearn et al., 1990) whereas flushing typically lasts five minutes or more and may be triggered by a variety of physical (e.g., alcoholic beverages, spicy foods, heat, sunlight, or exercise) and psychological stimuli (Kligman, 2004). For example, flushing can develop during repetitive or protracted embarrassment (e.g., Drummond et al., 2003; Drummond et al., 2007), and may also develop during psychological stress and emotions such as anger or shame (e.g., Drummond, 1999; Drummond and Quah, 2001). By-and-large, blushing and flushing are mediated by dilatation of superficial blood vessels in the forehead and cheeks which increases cutaneous blood flow and secondarily lifts facial temperature (Drummond and Lance, 1987; Shearn et al., 1990). The increase in facial blood flow may provide cues (e.g., sensations of engorgement or throbbing in the face, or facial warmth or sweating) which might, on one hand, raise personal awareness of blushing and, on the other, increase concerns about the blush being noticed by others. In people with social anxiety, hypervigilance toward and/or cognitive distortions about physiological cues could evoke embarrassment and elicit a blush, thereby intensifying physiological cues and promoting further embarrassment (Mulkens et al., 1999; Dijk et al., 2009b).
Although this cycle seems plausible, evidence is mixed. For example, in a study by Gerlach et al. (2001), ratings of blushing were greater in people with social anxiety disorder than in controls when they watched a videotape of themselves singing, held a conversation with a stranger of the opposite sex, and prepared and delivered a talk. Facial coloration was greater in people with social anxiety disorder than in controls when they first watched the videotape, but did not differ between groups during the other tasks. In a study in our laboratory, embarrassment and blushing ratings were greater in participants with a fear of blushing than controls during an introductory conversation, when they delivered a speech and when they listened to a recording of the speech (Drummond et al., 2007). Despite this, increases in forehead pulse amplitude were similar in both groups during each task. Nevertheless, pulse amplitude increased progressively over the course of the experiment in the high-fear group, suggesting that blushing provoked residual flushing after the emotions associated with blushing had subsided. Dijk et al. (2009b) investigated whether beliefs about blushing actually trigger blushing by assessing the effect of false feedback about blushing on facial coloration in people with high or low fear of blushing. Increases in facial coloration were similar in both groups in the false-feedback condition but were greater in the high- than low-fear group in a yoked-control condition. In addition, facial coloration was greater in the false-feedback than yoked-control condition in the low-fear group. Taken together, these findings suggest that anxiety about blushing (either pre-existing or prompted by false feedback) intensifies blushing in certain contexts and, additionally, provokes residual flushing during prolonged emotional distress.

To determine whether physiological cues of heightened blood flow feed into a cycle of escalating embarrassment and blushing, we administered 100 mg nicotinic acid (niacin) to healthy volunteers and measured changes in mood and facial blood flow (Drummond and Lazaroo, 2011). Niacin dilates superficial blood vessels in the upper chest, neck and face by
releasing prostaglandin D2 from epidermal Langerhans cells (Benyo et al., 2006), thereby evoking flushing for 30-90 minutes (Gille et al., 2008). When participants rested quietly, increases in blood flow were greatest in people with an elevated fear of negative evaluation (a cardinal feature of social anxiety). However, the niacin-induced flushing did not evoke psychological distress, possibly because contextual cues of blushing were absent.

To investigate this further in the present study, effects of niacin on mood and physiological activity were assessed in the same participants when they engaged in an embarrassing task (singing a children’s song). It was hypothesized that increases in facial blood flow evoked by niacin would heighten perceptions of blushing and would enhance embarrassment when participants sang. Whether changes in mood or physiological activity were most prominent in people with an elevated fear of negative evaluation was also investigated in retrospective exploratory analyses.

2. Methods

2.1 Participants

The sample consisted of 33 undergraduate university students aged between 18 and 41 years (mean age 24 ± 7 years). They were informed that niacin could cause facial flushing and that they would engage in potentially embarrassing tasks. None of the participants were pregnant, diabetic, had kidney or liver disease or took prescribed medication for any medical condition. They each provided informed consent for the procedures, which were approved by the Murdoch University Human Research Ethics Committee.

2.2 Procedures

The experiments were carried out in a temperature-controlled room maintained at 22 ± 1°C. To monitor changes in facial blood flow, a pulse transducer (photoplethysmograph, Grass Instruments, Quincy, MA) was attached to the right side of the participant’s forehead several cm above the eyebrow. This site was chosen because movement artifact is less problematic in
the forehead than at other facial sites that express blushing (Drummond and Lance, 1987; Drummond, 1997). The pulse transducer was covered with a black elastic headband to reduce interference from random illumination of the recording site. The headband was stretched slightly to hold the pulse transducer in place but was not tight enough to interfere with skin blood flow. Signals were sampled at 200 Hz by a Biopac MP100 data acquisition system and quantified using Biopac AcqKnowledge software (Version 3.9.0).

After facial blood flow had been recorded for three minutes, participants rated embarrassment, anxiety, blushing, facial heat, and two filler items (anger and tension) on 10 cm visual analogue scales. To minimize expectancy effects, drugs were administered double-blind and the code remained unbroken until the final participant had completed the experiment. In the niacin condition, four men and 13 women ingested a 100 mg immediate-release niacin tablet (Solaray dietary supplement, Nutraceutical Corporation, Utah, USA) enclosed in an opaque capsule. In the placebo condition, five men and 11 women ingested an identical opaque capsule that contained small sweets.

While waiting for the niacin to be absorbed, participants filled out several questionnaires including the Fear of Negative Evaluation Scale (Drummond and Lazaroo, 2011), a reliable and well-validated measure of this aspect of social anxiety (Watson and Friend, 1969; Clark et al., 1997). Approximately 20 minutes after they had ingested the niacin or placebo, participants rated embarrassment, anxiety, blushing and facial heat once again and were asked to sing “Old Macdonald had a farm” along with appropriate sounds for dogs, cats, ducks, pigs, cows, chickens, snakes, sheep, horses, monkeys and donkeys. A new sound was added after each verse. This procedure evokes embarrassment and increases forehead blood flow (Drummond and Lance, 1987; Drummond, 1997; Drummond and Lim, 2000; Drummond and Mirco, 2004). The investigator (DL) remained in the room to observe the participant while
he or she sang, and corrected mistakes. After six minutes of singing, participants rated embarrassment, anxiety, blushing and facial heat for a third time.

2.3 Data reduction and statistical approach

To minimize movement artifacts, the pulse waveform was filtered with a low pass filter at 4 Hz and a high pass filter at 0.5 Hz, and sharp spikes out of synchrony with the pulse waveform were deleted. Forehead pulse amplitude was measured as the peak-to-trough height of the filtered pulse waveform, with a greater difference indicating greater blood flow. Mean pulse amplitude levels were obtained for a two-minute period before drug administration, for two minutes before singing instructions were given, for the six minutes of the singing task, and for two minutes afterwards. As pulse amplitude is influenced by individual differences in the microarchitecture of cutaneous vessels and varies with skin opacity, pulse amplitude was expressed as a percentage of the level before drug administration. The mean pulse rate during each period of the experiment was also derived from the pulse waveform.

Physiological responses to singing were investigated in Drug (niacin, placebo) by Time (before singing, minute-by-minute during singing, and after singing) repeated measures analyses of variance with planned contrasts between levels before singing and each subsequent point. Similarly, ratings were investigated in Drug x Time (before niacin or placebo was administered, before singing, after singing) repeated measures analyses of variance with planned contrasts between consecutive data points. Fear of Negative Evaluation (high versus low) was included as an additional exploratory factor in these analyses. Scores on the Fear of Negative Evaluation scale average around 22 in people with social phobia (Beidel et al., 1985; Woody and Rodriguez, 2000). Therefore, six participants in the niacin condition and seven participants in the placebo condition with a score of 22 or more were considered to have an elevated fear of negative evaluation, whereas another 11 participants in the niacin condition and nine participants in the placebo condition had low scores.
Results are reported as the mean ± standard error, and p<0.05 was regarded as statistically significant.

3. Results

3.1 Effects of niacin on physiological activity

As shown in Figure 1, forehead pulse amplitude was greater in the niacin than placebo condition in participants with an elevated fear of negative evaluation. This difference was present before singing and persisted during singing [main effect for Drug F(1,29) = 8.52, p<0.01, partial $\eta^2 = 0.227$; Drug x Fear of Negative Evaluation F(1,29) = 10.03, partial $\eta^2 = 0.257$]. During the first minute of singing, pulse amplitude increased in the niacin group but not in the placebo group [Time (baseline to first minute of singing) x Drug F(1,29) = 5.84, p<0.05, partial $\eta^2 = 0.168$], and diverged between participants with high versus low fear of negative evaluation; specifically, pulse amplitude increased in the low-fear group but, on average, remained stable in the high-fear group [Time (baseline to first minute of singing) x Fear of Negative Evaluation F(1,29) = 4.90, p<0.05, partial $\eta^2 = 0.145$] (Figure 1).

Before singing, pulse rate was similar in the niacin and placebo conditions and in participants with high versus low fear of negative evaluation scores. Pulse rate increased significantly during singing and returned to baseline afterwards [main effect for Time, F(3.19, 92.57) = 33.5, p<0.001 after Greenhouse-Geisser correction to the degrees of freedom, partial $\eta^2 = 0.536$] (Figure 2). Planned contrasts indicated that increases were greater in participants in the niacin than placebo condition during the third, fifth and sixth minutes of singing [Time (baseline to the third minute of singing) x Drug F(1,29) = 4.31, p<0.05, partial $\eta^2 = 0.129$; Time (baseline to the fifth minute of singing) x Drug F(1,29) = 5.02, p<0.05, partial $\eta^2 = 0.148$; Time (baseline to the sixth minute of singing) x Drug F(1,29) = 7.28, p<0.05, partial $\eta^2 = 0.201$]. In addition, increases were greater in participants with high than low fear of negative evaluation across all time points [Time x Fear of Negative Evaluation F(3.19, 92.57) = 2.93,
p<0.05, partial $\eta^2 = 0.092$], more so in the niacin than placebo condition during the second and sixth minutes of singing [Time (baseline to the second minute of singing) x Drug x Fear of Negative Evaluation F(1,29) = 4.90, p<0.05, partial $\eta^2 = 0.144$; Time (baseline to the sixth minute of singing) x Drug x Fear of Negative Evaluation F(1,29) = 5.90, p<0.05, partial $\eta^2 = 0.169$].

3.2 Self-report ratings

Ratings of embarrassment, anxiety, blushing and facial heat remained fairly stable after drug administration but increased significantly on the 10 cm visual analogue scales during singing [Time (before to after singing): for embarrassment 0.6 ± 0.2 to 3.6 ± 0.5 cm, F(1,29) = 37.2, p<0.001, partial $\eta^2 = 0.562$; for anxiety 1.3 ± 0.3 to 2.3 ± 0.4 cm, F(1,29) = 7.48, p<0.05, partial $\eta^2 = 0.205$; for blushing 1.0 ± 0.3 to 3.2 ± 0.5 cm, F(1,29) = 23.7, p<0.001, partial $\eta^2 = 0.450$; for facial heat 1.4 ± 0.4 to 3.2 ± 0.5 cm, F(1,29) = 14.5, p<0.001, partial $\eta^2 = 0.341$]. Increases in ratings of facial heat were greater during singing in participants with high than low fear of negative evaluation [from 1.5 ± 0.7 to 4.3 ± 0.8 cm and 1.4 ± 0.5 to 2.1 ± 0.6 cm respectively, Time (from before to after singing) x Fear of Negative Evaluation F(1,29) = 5.59, p<0.05, partial $\eta^2 = 0.166$]. However, ratings were similar in the niacin and placebo conditions (none of the Drug main effects, Drug x Time interactions, or Drug x Time x Fear of Negative Evaluation interactions were statistically significant).

4. Discussion

The primary aim of this study was to determine whether the vasodilator niacin would augment perceptions of blushing or supplement embarrassment during an embarrassing task (singing a children’s song). Compared with placebo, niacin increased forehead pulse amplitude when participants first started to sing. In addition, increases in pulse rate were greater at certain stages of singing in the niacin than placebo condition and, in an exploratory analysis, were greater throughout the task in people with high than low fear of negative
evaluation. Nevertheless, neither niacin nor fear of negative evaluation influenced mood or blushing ratings during singing within the constraints of our experiment. Thus, sensory cues associated with increased facial blood flow and pulse rate did not appear to augment perceptions of blushing or enhance embarrassment, even in participants with an elevated fear of negative evaluation.

4.1 Physiological effects of niacin

Niacin is employed in doses of up to 4 g per day to increase the plasma concentration of high density lipoprotein cholesterol, thereby slowing the progression of atherosclerosis and lowering the risk of adverse cardiovascular events (Gille et al., 2008). Flushing can become problematic at high doses (Davidson, 2008; Gille et al., 2008) but is more sporadic at doses of 50-100 mg (Bouwer and Stein, 1998; Schweikart et al., 2009). Pulse amplitude increased sharply in the niacin condition when participants started to sing, suggesting that blushing was superimposed on niacin-induced flushing. Whether fear of negative evaluation impacted directly on this response is uncertain, because the vasodilator effects of niacin were greater in the high- than low-fear group before singing started (Drummond and Lazaroo, 2011). The mechanism of this heightened vasodilator response is unclear but could be due to physiological rather than psychological factors, because niacin had no effect on mood ratings or sensory cues of blushing at any stage of the experiment.

Pulse amplitude (an index of blood flow) typically increases in forehead vessels during the embarrassment evoked by singing (Drummond and Lance, 1987; Drummond, 1997; Drummond and Lim, 2000; Drummond et al., 2003; Drummond and Mirco, 2004). Surprisingly, however, forehead pulse amplitude generally decreased in the placebo condition during the first minute of singing in participants with an elevated fear of negative evaluation. Blushing forms part of a broad increase in sympathetic activity characterized by increases in heart rate, sweating and decreases in blood flow through the fingers (Shearn et al., 1990;
Drummond, 1994; Gerlach et al., 2001; Voncken and Bögels, 2009). However, fear and certain forms of embarrassment are associated with decreases in facial blood flow that may sometimes override blushing during psychological arousal (Hare, 1973; Drummond, 2001; Drummond and Quah, 2001). Thus, the present findings suggest that contextual factors concerning the experimenter, instructions or experimental setting enhanced sympathetic vasoconstriction or inhibited active sympathetic vasodilatation in the placebo condition in participants with an elevated fear of negative evaluation.

Pretreatment with niacin boosted pulse rate during the latter stages of singing, particularly in participants in the high-fear group. A potential explanation for this is that singing evoked a stronger emotional reaction in participants with high than low fear of negative evaluation, and that niacin augmented the physiological component of this response. Nevertheless, niacin appeared to have little effect on mood ratings or perceptions of blushing, even in participants with augmented physiological activity.

4.2 Psychological effects of niacin

Contrary to expectations, niacin did not influence ratings of blushing or embarrassment either before or during singing. Although this might have been due to lack of statistical power, this seems unlikely because niacin had a minimal effect on self-report ratings (partial $\eta^2 \leq 0.031$). Thus, sensory cues of blushing and embarrassment apparently did not build upon each other within the constraints of our study. Our preliminary findings run counter to the view that such cues intensify embarrassment and elicit a blush, thereby strengthening physiological cues in a vicious circle (Mulkens et al., 1999; Dijk et al., 2009b). However, evidence from various sources suggests that changes in facial blood flow may play only a minor role in the subjective experiences associated with blushing, at least in normal volunteers. For example, scores on the Blushing Propensity Scale (an estimate of how frequently people blush in various situations) appear to be linked more closely with self-focused attention and heightened social anxiety than
with blushing *per se* (Leary and Meadows, 1991; Neto, 1996; Bögels et al., Drummond, 1997; Mulkens et al., 1997; Mulkens et al., 1999). Indeed, changes in facial blood flow generally bear little relation to blushing propensity scores during discrete episodes of embarrassment (Drummond, 1997; Mulkens et al., 1997; Mulkens et al., 1999; Gerlach et al., 2001) or to negative affect during psychological stress (Vassend and Knardahl, 2005; Drummond and Chen, 2008). For example, Vassend and Knardahl (2005) reported that changes in facial blood flow during various experimental tasks (reading aloud, delivering a speech and tracking the movement of a target on a computer screen) were unrelated to personality dimensions or to ratings of negative affect. Similarly, in a study in our laboratory, increases in facial blood flow evoked by eye contact were unrelated to ratings of negative affect or to the intensity of blushing or other somatic symptoms (Chen and Drummond, 2008). Likewise, false feedback about blushing appears to impact strongly on ratings of embarrassment and blushing but evokes only subtle changes in facial blood flow that depend on prior expectations about blushing (Drummond, 2001; Drummond et al., 2003; Dijk et al., 2009b). Thus, people may focus on cues over and above those directly associated with changes in facial blood flow when they decide whether or how intensely they are blushing. What these cues are remains uncertain, but might include appraisal of the situational context or emotions such as embarrassment, guilt or shame.

Both in the niacin and placebo conditions, ratings of facial heat increased more during singing in participants with high than low fear of negative evaluation. Similarly, in a previous study, facial heat ratings increased more in a high- than low-fear group when they sang (Chen and Drummond, 2008); despite this, increases in facial blood flow were similar in both groups. Together, the findings suggest that hypervigilance toward physiological cues of anxiety, and/or cognitive distortions concerning physiological activity, are associated with a fear of
negative evaluation. These psychological influences may have augmented pulse rate during singing, but apparently had little effect on blushing.

4.3 Limitations

A major limitation of this study is the small number of participants, especially after retrospective allocation into groups with high or low fear of negative evaluation. Thus, we may have overlooked important effects due to lack of statistical power. Accordingly, the present preliminary findings await verification in larger, more representative samples selected to be high or low on characteristics of interest (e.g., fear of negative evaluation or blushing). In particular, it is important to determine whether the findings generalize to participants with an extreme fear of blushing or other debilitating aspects of social anxiety, as this might have etiologic and treatment implications. For example, an escalating of cycle of blushing and embarrassment might contribute to fear of blushing (Mulkens et al., 1999; Dijk et al., 2009b), whereas cues of blushing either are overlooked or do not distress people without this fear.

We investigated the effects of niacin on the transient blushing evoked by singing a children’s song. It would be interesting to explore the effect of niacin-evoked flushing on the subjective experience of more intense or persistent emotions in future studies (e.g., emotions such as anger, anxiety or shame, or changes in mood evoked by psychological stress), to determine whether niacin pretreatment primes these emotions.

One of the strengths of our study is that drugs were administered double-blind. Although we did not formally evaluate whether this blinding was successful, the lack of difference between the niacin and placebo conditions in ratings of blushing and facial heat suggests that most participants were unaware of their group allocation. However, swallowing a capsule that potentially contained niacin could have altered the psychological impact of the singing task as sensory cues of blushing might have been attributed to the vasodilator effects of niacin. This requires further investigation.
An additional limitation was that only a single low dose of niacin was administered to minimize sensations associated with increased facial blood flow before the singing task began. It would be interesting to investigate effects of higher doses of niacin to determine whether participants with a fear of blushing are frightened by overt physiological cues of flushing, and whether these cues influence emotional reactions in embarrassing or anger-provoking situations.

4.4 Conclusions

Our preliminary findings suggest that increases in facial blood flow during embarrassment do not necessarily increase perceptions of blushing or embarrassment, even in people with an elevated fear of negative evaluation. Thus, perceptions of blushing may stem more from contextual or emotional factors than from physiological cues. Cognitive therapy aims to rectify faulty beliefs about the causes and consequences of blushing in people who are frightened of this response. This technique supplements interventions that seek to direct attention away from thoughts of blushing or to reduce bodily tension (Bögels, 2006), and may also complement mindfulness- or behaviourally-based treatments (Mulkens et al., 2001; Bögels et al., 2006; Bögels and Voncken, 2008; Chaker et al., 2010). Challenging assumptions about the perceptual cues associated with blushing may help to further refine the cognitive approach and strengthen treatment gains.
References


Figure legends

Figure 1. Mean change (± S.E.) in pulse amplitude (a) in participants with high fear of negative evaluation and (b) in participants with low fear of negative evaluation who ingested 100 mg niacin (filled circles) or placebo (open circles). Pulse amplitude is expressed as the percent change from the baseline recorded before drug administration.

Figure 2. Mean change (± S.E.) in pulse rate (a) in the placebo condition and (b) in the niacin condition in participants with high (open circles) or low (filled circles) fear of negative evaluation.