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ORIGINAL PAPER

How Weeping Influences the Perception of Facial Expressions: The Signal Value of Tears

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Abstract
Emotional tears have been proposed to serve as a signal of distress, appeasement, and helplessness, which promotes prosocial responses in observers. They may also facilitate the perception of sadness. A still unanswered question is what information tears convey about emotional states when they are combined with different muscular facial expressions. The current study evaluated three hypotheses: Tears facilitate inferences about (a) emotion intensity in general (b) sadness in particular, or (c) helplessness-related appraisal and behavioral intentions. In the first experiment, participants viewed pictures of (non)tearful real and artificial faces displaying anger, disgust, fear, happiness, sadness, surprise, and neutral state. They had to report which of the seven expressions they recognized, and to rate its intensity, sincerity, and felt empathy. Tears appeared to facilitate the perception of sadness, but also of anger and fear, while they decreased the perception of disgust and surprise. The ratings of the intensity, the perceived sincerity, and the experienced empathy followed a similar pattern. In the second experiment, participants had to indicate if briefly (50 ms) presented (non)tearful faces showed a particular expression, and we measured their accuracy and reaction times. The results of the first experiment were not corroborated. Overall, the findings lend most support to the appraisal/behavioral intentions hypothesis and less support for the intensity and the sadness enhancement hypotheses.

Keywords Emotional tears · Signaling functions · Facial expressions · Emotional intensity · Sincerity · Empathy

Introduction

Which emotional states do observers associate with the production of tears? A recent lexical study demonstrated that people associate the words tears and crying mostly with sadness (De Deyne et al. 2012). In addition, experimental studies have shown that visible tears

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increase the observer's perception of sadness across various expressions (Provine et al. 2009; Reed et al. 2015). This *tear effect* (Provine et al. 2009) was found even at the pre-attentive level, as evidenced by faster recognition of sadness when sad expressions contained tears, without the respondents being aware of their presence (Balsters et al. 2013). However, tears do not seem to be linked *exclusively* to sadness (see e.g., Darwin 1872) or any other specific "basic" emotion (Ekman 1992), but rather to various positive and negative emotional states, particularly those in which a prosocial reaction is desired from others (Gračanin et al. 2018). Research on the antecedents of crying (Vingerhoets 2013, Vingerhoets et al. 1997) consistently revealed a broad range of emotional states and appraisals that subjectively accompany tears, including sadness, relief, grief, raptness, joy, self-pity, hopelessness, anger, and frustration. It also appears that crying is often accompanied by a blend of emotions, rather than one discrete emotion at a time, with helplessness or powerlessness as its key feature (Crile 1915; Frijda 1986; Miceli and Castelfranchi 2003; Vingerhoets et al. 1997). Therefore, the question if tears signal (and thus facilitate perception of) one or more emotional states, appraisals, or behavioral intentions remains unresolved. Furthermore, how we perceive emotions in facial expressions is not a fixed given, but rather depends on other visible reaction patterns (e.g., body language; Van den Stock et al. 2007) and the context (Carroll and Russell 1996). In that regard, tears might help to contextualize and disambiguate muscular facial expressions. We here report on two experiments in which we explored the perception of tears in interaction with muscular emotional expressions. The results are expected to inform us about the expresser's states that observers associate with tears, and more generally, about the signaling value of tears.

Theoretically, the following three partly overlapping hypotheses can be formulated to address the question about interactive effects of tears and facial expressions: First, tears could be frequent "companions" of different intense emotional states (Kottler and Montgomery 2001; Vingerhoets and Bylsma 2016). Consequently, tears may influence the perception of different emotional expressions merely or predominantly in terms of the perceived *intensity* of these expressions (intensity hypothesis, *IH*; also termed as general enhancement hypothesis; Ito et al. 2019). Alternatively, if tears are related explicitly to sadness, then their presence should facilitate the perception of that specific emotion (i.e., sadness) by observers (sadness enhancement hypothesis, *SEH*; Ito et al. 2019). Third, tears may affect inferences about different expressions because they communicate the presence of specific appraisals and/or (lack of) corresponding behavioral intentions (appraisal/behavioral intentions hypothesis, *ABIH*; Clore and Ortony 2008; Frijda 1986; Scherer et al. 2017). Here, the emotions are seen as states with blurry boundaries that do not have distinctive facial expressions. Instead, they involve combinations of processes such as core affect, appraisals, behavioral intentions, and facial expressions that are tied to prototypical situational triggers (Barrett 2006). Cognitive appraisals, as critical responses to these triggers, shape general affective reactions into more specific emotions (Clore and Ortony 2008), while the labels of these distinct emotions (e.g., sadness or fear) stem primarily from everyday folk categorization (Russell and Barrett 1999). Within such a framework, the findings mentioned above about helplessness and the related need for support being the core state related to crying episodes (e.g., Vingerhoets et al. 1997) imply that the helpless appraisal might represent a useful clue in the search for the signaling value of tears.

The importance of helplessness as a primary trigger of tears is highlighted by findings showing that tearful individuals are perceived as having a greater need for social support than these individuals with the same expression but without visible tears (Balsters et al. 2013; Vingerhoets et al. 2016). Further, tearful individuals more likely receive help and comfort from observers (Hendriks and Vingerhoets 2006), and the wish to help is mediated by the observers' own felt sadness when viewing the tears (Küster 2018). These findings fuelled the hypothesis that tears, as an expression that is closely linked with a state of helplessness, represent a signal of (the lack of any) specific behavioral intentions (see also Gračanin et al. 2018). It is also plausible that these intentions are coupled with a corresponding appraisal (e.g., "the situation is helpless" or "I [the crier] desire the proximity of a supportive person"). Crucially, appraisals and/or (the lack of) behavioral intentions that are typically associated with tears may be characteristic of more than one distinct emotion. Then, if the exposure to tears facilitates inferences about a state of helplessness (e.g., Balsters et al. 2013) and the passivity of the crier (Gračanin et al. 2018), it can be expected that tears will facilitate the perception of expressions of those emotions that involve such appraisals and intentions. The attribution of helplessness may be linked to expressions of several emotions such as sadness, anger, and fear, while it is hardly expected to be related to facial expressions of disgust, surprise, and happiness (see, e.g., Ellsworth and Smith 1988). Therefore, if the *ABIH* is to be supported, the presence of tears should facilitate the recognition and the functional reactions to the former rather than to the latter set of expressions. While there is a possibility that emotions such as happiness or surprise might also include some helplessness (e.g., when being overwhelmed with a strong and unexpected positive emotion in a social situation), exploration of such instances might also require the consideration of other types of "secondary" positive emotions such as gratitude or awe.

In the current work, we used Ekman's original basic emotional expressions as a starting point, while we keep open the possibility that tears might facilitate perception of the expressions related to other social emotions. Furthermore, there is a certain necessary overlap between the *ABIH* and the other two hypotheses in that if the *ABIH* is to be supported, the tears should facilitate responses to sad expressions (also supporting *SEH*) and they should promote the perception of the intensity of more than one expression (also supporting *IH*). However, for the *ABIH* to be supported, tears should also facilitate responses to expressions other than sadness, and they should influence the perception of the intensity of several specific, but not all of the presented expressions. Therefore, both the *ABIH* and *SEH* are more specific than the *IH*, so that if the three hypotheses are evaluated in the context of a limited range of emotional expressions (or for each expression separately), then the presence of the support for the *ABIH* and *SEH* necessarily implies support for the *IH*. However, the support for the *IH* in certain cases disconfirms the other two hypotheses. Finally, the presence of the support for the *ABIH* in certain cases also disconfirms the *SEH*, but not vice versa.

Emotional states (as well as expressions) are not associated with specific appraisals and intentions in a one-to-one manner. Specifically, sadness, in accordance with its help-soliciting functions, has the highest correspondence with helpless appraisal (i.e., low situation controllability; Ellsworth and Smith 1988) and associated lack of intentions (Barr-Zisowitz 2000). However, while anger generally facilitates intentions to remove obstacles actively, this emotion may occasionally also involve appraisal of helplessness (Berkowitz and Harmon-Jones 2004), which eventually leads to *frustration*, a boundary state between anger and sadness that is commonly reported to accompany crying (Vingerhoets et al. 1997). In addition, the appraisal of other-agency (other's responsibility and control of the situation), which is a crucial cognitive aspect of both anger and sadness (e.g., Ellsworth and Smith 1988), fits perfectly with the help-soliciting and aggression reduction functions of tears (Gračanin et al. 2018). Finally, fear may typically stimulate active fight or flight behavior or inhibit all behavior (freezing, giving up, fainting). Similarly, an accompanying appraisal might include the perception of the necessity to react actively or to stay passively, with the former being a more prototypical human fear response (Öhman 2010). Therefore, if the *ABIH* is to be supported, the impact of tears on facial expression recognition accuracy should differ among expressions as a function of the associated helplessness-related appraisal and intentions.

Which of these three hypotheses is presently best supported by previous findings? Inconsistent with predictions from *IH*, Reed et al. (2015) observed that some (e.g., happy and fearful) but not all (non-Duchenne smile and even sad) expressions were rated as having a higher intensity when presented with tears. Moreover, Ito et al. (2019) found that participants perceived the expressions of anger, fear, disgust, and neutral expression with tears as having a higher intensity of sadness relative to other emotional categories (anger, fear, and disgust), although the intensity of anger increased to some extent as well. However, both studies assessed responses to a limited number of facial expressions. Consequently, it may still be too early to dismiss the *IH*. Conversely, both *SEH* and *ABIH* have received partial support. When Reed et al. (2015) asked participants to report on the presence of discrete emotions visible in each presented expression, the exposure to different expressions with tears resulted in an increased perception of negative emotions (sadness, anger, and fear) across several expressions (happy, sad, angry, fearful). In contrast, Ito et al. (2019) concluded that tears primarily reinforce the perceived (intensity of) sadness. Given these inconsistent findings, the present study tested each of the three hypotheses by carefully examining the interactive effects of tears and a wider range of expressions on both the perception of emotions and on a group of additional theoretically relevant responses.

A better understanding of the interplay between tears and muscular expressions also requires a consideration of other theoretically relevant effects of tears as observed in previous studies, such as their influence on the perceived sincerity of the depicted individual and the degree of empathy felt toward him or her (e.g., Zeifman and Brown 2011). In contrast to most emotional expressions, crying is hard to fake, which makes it similar to the Duchene smile, laughing, and blushing (Provine 2012; Vingerhoets 2013). Correspondingly, there are many lay accounts of tears as a display of genuine emotion (Kottler and Montgomery 2001; Vingerhoets 2013), which recently received empirical support (e.g., Picó et al. 2020). In addition, participants report more empathy for crying than for non-crying individuals (e.g., Zeifman and Brown 2011). Previous research did not explore the potential influence of adding tears to different emotional expressions on perceived sincerity and empathy, which is unfortunate since both represent fundamental mechanisms supporting the inter-personal functions of tears (Gračanin et al. 2018), and their assessment might provide additional knowledge about the interactive effects of tears and muscular expressions. We expect that if tears impact the recognition and perceived intensity of discrete emotional expressions, that would also imply corresponding changes in attributed sincerity and felt empathy. The testing of that specific hypothesis represents a further evaluation of each of the three more general hypotheses described above.

The Present Studies

To evaluate the above-formulated hypotheses, we designed two experiments enabling us to examine the combined effects of tears and facial expressions of disgust, fear, happiness, sadness, surprise, anger, and a neutral expression on several dimensions of observer responses. Specifically, we measured the speed and accuracy of expression recognition, the perceived intensity and sincerity of the emotional expression, and the degree of empathy felt for the depicted models. Our study furthermore added tears to emotional expressions not only of real faces (RF) but also to artificial faces (avatars; AF), allowing us to increase the range of the stimuli and also to avoid using the (human) posed expressions only. In this way, we increased the generalizability of our findings, and we were also able to validate the artificial faces for future work using virtual reality. In addition, the design of AF provided greater control over expression intensity across different exemplars.

Study 1

Study 1 evaluated the evidence for each of the three hypotheses: tears facilitate the inferences about (a) emotion intensity in general (*IH*) (b) sadness in particular (*SEH)*, or (c) expressions that signal helplessness-related appraisal and behavioral intentions (*ABIH)*. The *IH* is supported if tears have comparable effects on the perceived presence and intensity of all displayed expressions. Support for the *SEH* would imply that tears primarily facilitate the recognition and perceived intensity of sadness. Finally, the *ABIH* is supported if tears promote the recognition and perceived intensity of different expressions depending on the level to which these emotions are related to specific appraisals and behavioral intentions. In this case, tears would specifically facilitate the recognition of the expression of those emotions that are related to the appraisal of helplessness and the related lack of behavioral intentions, driving the need of others to react prosocially. The most substantial effects can then be expected for sadness, arguably somewhat smaller effects for fear and anger, and a notable lack of effects for other expressions. Study 1 additionally tested whether tears promote the perception of sincerity and feelings of empathy towards expressing individuals across different expressions in accordance with each of these three hypotheses. We focused on the effects of tears in (a) all expressions, irrespective of whether they were identified correctly, and additionally (b) only in those expressions that were identified correctly (in accordance with pre-defined labels), allowing us to also explore the interaction between tears and *attributed* specific facial expressions.

Method

Participants

Sixty students (43 females; mean age = 20.17, *SD* = 2.52) participated in the study for course credits. The sample sizes of 60 (Study 1) and 44 (Study 2) exceeded the required sample sizes of 53 and 40, respectively, based on a-priory power analysis (power = 0.85, $\alpha = 0.05$ and median effect sizes $d = 0.42$ and $d = 0.49$) conducted using the software G*Power 3 (Faul et al. 2007). These expected effect sizes were based on the results of comparable studies (Reed et al. 2015; Balsters et al. 2013). Ethical approval was obtained by the faculty ethics committee. All participants gave their informed consent before we started the experiment.

Materials

The pictures depicting emotions conveyed by RF were selected from the Karolinska Directed Emotional Faces database (KDEF, Lundqvist et al. 1998). Tears were digitally added to portrait pictures of four randomly selected KDEF models (two women: AF07, AF32, and two men: AM11 and BM30). Each model expressed one of the six emotions (disgust, fear, happiness, sadness, surprise, and anger) or had a neutral expression.

Therefore, from 28 original pictures (4×7), 28 pictures with tears were created, resulting in a set of 56 pictures of RF expressing six different emotions and neutral state, with and without tears. The 56 photographs of expressions of the same type for AF with and without tears were created by one of the co-authors (DK), using Poser Pro (2014) and Luxrender (v1.6), with the help of a certified FACS coder. The expressions were created using a combination of the premade morph packages and custom-built morphs using the Poser morph tool. The intensity of the expressions was aimed to match those of the KDEF images, with additional morph settings to ensure that high intensities (roughly corresponding to FACS intensity score E) could be achieved without creating breaks and "poke through" in the mesh. The tears were created in Poser as custom-made tear material. The final, complete set of stimuli contained 112 pictures, including four RF and four AF, each expressing six different emotions and a neutral state, with and without tears (see examples in Fig. 1a and b). The perception of realism and recognition rates of targeted expressions in newly developed pictures were evaluated in two pilot studies (see electronic supplementary materials) and may be considered as satisfactory for the current Studies 1 and 2. The stimulus set consisting of AF from both studies, as well as the raw data and codes from both pilot and central studies, are available at https://osf.io/dx8cg/. The adapted KDEF stimuli used in Study 1 and Study 2 are available at https://www.kdef.se/.

Procedure

After having signed the informed consent and having completed a brief demographic questionnaire, participants were individually seated in front of a 29-in. monitor. They underwent a computer-administered face rating task controlled by the program Qualtrics. Each picture was presented for 4 s, after which participants provided three ratings, always in the same order: (1) the intensity of the expression was measured with the question "How intense was the expressed emotion?" (2) sincerity: "How sincere was the expressed emotion?", and (3) empathy: "How much empathy do you experience for this person?". Answers were given on a 9-point Likert scale ranging from 1 (*emotion absent / not sincere at all / no empathy at all) to 9 (maximum intensity / sincerity / empathy*). Next, participants were asked to match each face with one of the seven emotion words that best described the expression category displayed by pressing the corresponding key. To avoid fatigue effects and to increase the measurement reliability, two participant groups were created randomly, each being exposed twice to half of the stimulus material. To that aim, two fixed stimulus sets (set A, RF models: AM11, AF07; AF models: Edinburgh, London; set B, RF models: BM30, AF32: AF models: Aram, Tokio) were created. Therefore, each participant was exposed to 56 different pictures twice. After the first randomized presentation (the whole stimulus set A or B) and a 2-min break, participants underwent the same procedure again. The experiment lasted approximately 30 min.

Data Analysis

All the analyses were conducted separately for the RF and AF. We first calculated the percentages of labeling of each of the seven presented expressions by using each of the (labels of) seven expressions (emotion categories) among which the participants could choose. Due to several observed differences between the groups that were exposed to the two stimulus sets on the dependent variables, the variable stimuli set was controlled for in all subsequent analyses. The effects of tears on emotion recognition accuracy rates were

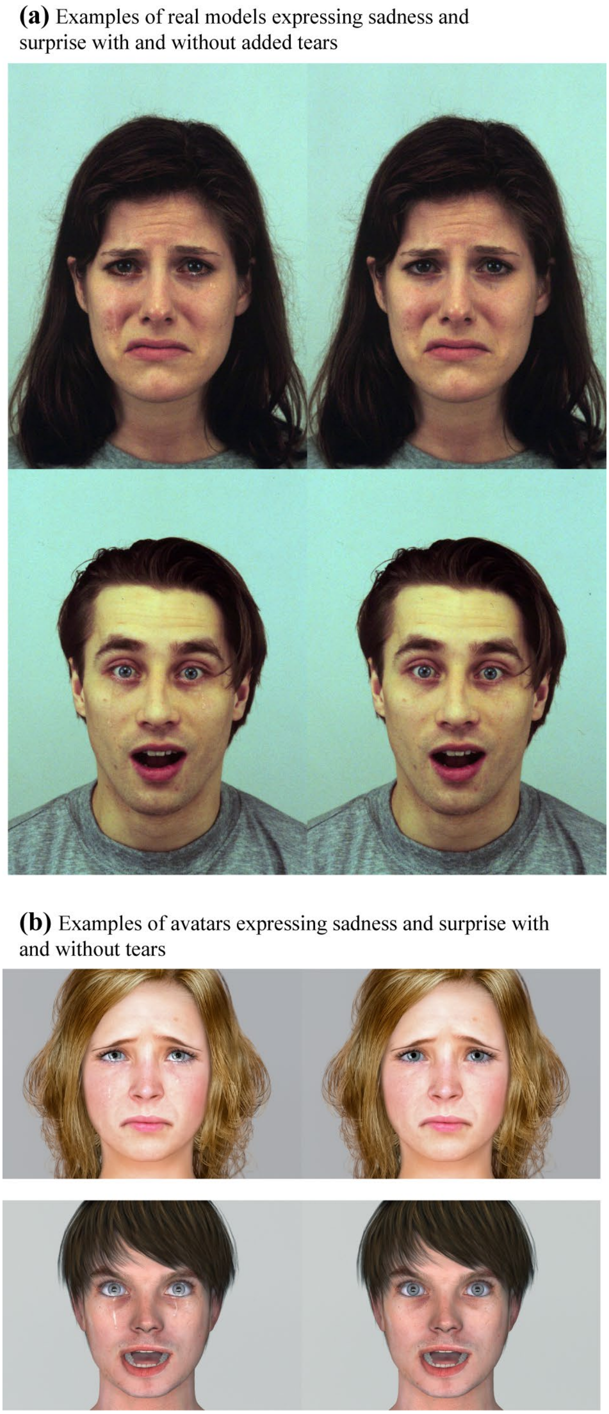

Fig. 1 **a** Examples of real models expressing sadness and surprise with and without added tears. *Note*. Pictures represent original (right) and edited (left) KDEF pictures *AF07* and *BM25*. **b** Examples of avatars expressing sadness and surprise with and without tears. *Note*. Pictures represent models *London* and *Edinburgh* from the newly created set of avatars

computed using two mixed ANOVAs, with the factors emotion (seven expressions) and tears (tears/no-tears) as repeated factors, and stimuli set (A or B) as a between-subjects factor. Greenhouse–Geisser corrections were employed in order to adjust for the repeated factors with more than two levels. We also created two confusion matrices showing which emotion categories were attributed to the presented expressions, depending on the presence of tears. Next, to evaluate the effects of tears on each of the three dependent variables (intensity, sincerity, and empathy), two groups (RF and AF) of seven 2×2 mixed-model ANOVAs (one for each expression) were performed, with stimuli set as between- and tears as a within-subjects factor. We first analyzed all the data and, additionally, only the responses on the accurately labeled expressions. The high frequency of mislabeled expressions resulted in a large proportion of missing values in the latter case, making the application of one MANOVA, or three $7 \times 2 \times 2$ ANOVAs including all the expressions, infeasible. Thus, in order to be able to compare the analysis of all responses with the analysis of the correct responses only, in both cases, we conducted seven ANOVAs (with Bonferroni correction for multiple tests), one for each expression.

Results and Discussion

Figure 2 shows the two confusion matrices with the percentages of correct recognitions of each presented expression, as well as the percentages of all possible misattributed cases, also for each presented expression, separately for no-tears and tears conditions.

First, regarding the faces without tears, we expected the highest recognition percentages to appear in the diagonals, so that, for example disgusted faces were most frequently labeled as expressing disgust. As is evident from both matrices, this expectation was generally supported, except for the fearful expressions, which were recognized least accurately (22.08% in RF and 46.25% in AF). Most important for our hypotheses are the changes in the results displayed in the diagonals (accuracy rates) when tears were added. Both ANOVAs showed a significant main effect of tears (RF: $F(1,58) = 92.93$, $p < .001$, $\eta_p^2 = .62$; AF: $F(1,58) = 160.98$, $p < .001$, $\eta_p^2 = .74$) and emotion (RF: $F(4, 236) = 149.87$, $p < .001$, $\eta_p^2 = 0.72$; AF: $F(3, 196) = 49.53$, $p < .001$, $\eta_p^2 = .46$). The main effect of emotion was expected, as illustrated by clear differences in the recognition accuracy between fear and the other expressions mentioned above (cf. Calvo and Lundqvist 2008). Moreover, tears decreased the overall recognition accuracy (RF: from 0.80 to 0.69; AF: from 0.77 to 0.59). This effect can be better understood in relation to the significant interaction between tears and emotion (RF: $F(4, 253) = 30.98$, $p < .001$, $\eta_p^2 = .35$; AF: $F(5, 272) = 86.20$, $p < .001$, $\eta_p^2 = .60$), which was further decomposed by a, Bonferroni corrected, comparison between the tears and the no-tears condition for each expression. This comparison revealed that tears significantly and consistently (for both RF and AF) *decreased* the recognition accuracy for disgust (RF: $\eta_p^2 = 0.55$; AF: $\eta_p^2 = 0.33$), surprise (RF: $\eta_p^2 = 0.23$; AF: $\eta_p^2 = 0.41$), and neutral expressions (RF: $\eta_p^2 = 0.54$; AF: $\eta_p^2 = 0.87$), whereas they *increased* the recognition accuracy for sad ($\eta_p^2 = 0.21$) and angry ($\eta_p^2 = 0.22$) expressions in RF only.

When tears were added, some expressions were perceived differently than in the tearless condition (Fig. 2). What was the pattern of these changes? First, the addition of tears facilitated the recognition of sadness across all presented expressions. Further, it made disgust faces to be labeled more often as angry. Interestingly, it also resulted in fearful faces being less often mistakenly labeled as surprised, which resulted in fear becoming the most frequent label for the fear expression (in AF only). Relatedly, surprised faces (especially AF) were more often regarded as fearful. Finally, angry RF expressions were most

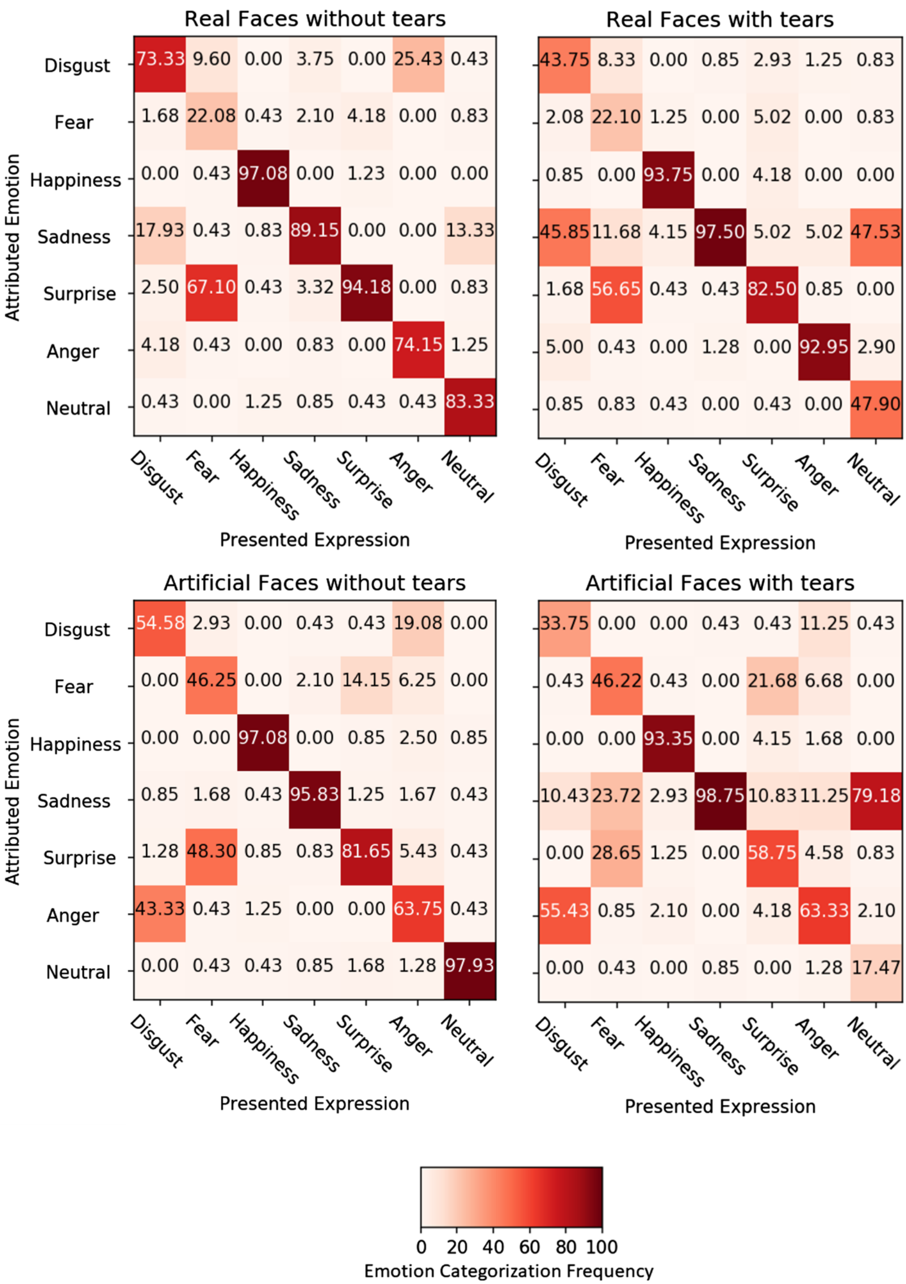

Fig. 2 Confusion matrices showing percentages of correctly recognized emotional expressions of the **a** real faces and **b** artificial faces, with and without tears ($N = 60$)

often misclassified as disgusted, while this misattribution rate fell to almost zero with tears added, and the correct recognition of anger substantially increased, implying that tears facilitated the perception of anger at the cost of disgust.

Intensity, Sincerity, and Empathy

With tears present, the expressions of fear, sadness, surprise, and anger were consistently (for both RF and AF) perceived as more intense (Table 1). In the accurately assigned expressions only (see supplementary materials), the effects were comparable, except that those for surprise and fear now disappeared. Further, the expressions of sadness (in RF only) and anger (consistently) were perceived as more sincere, and they consistently evoked more empathy when coupled with tears (Tables 2 and 3). Fearful faces with tears also evoked more empathy (in AF only). The effects of tears on sincerity and empathy in the accurately assigned expressions were comparable (except for non-significant results for angry and fearful AF, clearly due to the smaller number of cases).

Interestingly, tears also consistently increased the reported empathy for the depicted models with a neutral expression, and they decreased the perceived sincerity of happy expressions in RF only. This was not observed when only correct recognitions were analyzed, amongst others, because tearful neutral expressions were perceived more often as sad (Fig. 2), and only as such, the depicted models received more empathy. The remaining significant changes were not reliable, that is, they were either relatively small or observed for either RF or AF only.

In short, in Study 1, tears generally decreased recognition accuracy, specifically, for disgusted, surprised, and neutral expression. However, tears also facilitated the perception of sadness and anger, whereas they did not affect or even slightly promoted the perception of fear. The results regarding intensity, sincerity, and empathy corroborated the findings on accuracy. Taken together, this pattern of findings provides more support for the *ABIH* than for both alternative hypotheses. More specifically, the least support was found for the *IH*, since the presence of tears increased the intensity ratings for only a limited group of expressions. Regarding *SEH*, the primacy of the sadness expressions (for example, in being recognized/perceived more often and as more intense when tears were present), in comparison to other expressions, makes it premature to dismiss this hypothesis completely.

Study 2

Study 2 aimed to replicate and extend the findings of Study 1 by using a different methodological approach. Specifically, we narrowed our focus on the ability of tears to influence the recognition of different facial expressions during a brief presentation. As in Study 1, we tested the influence of tears on the attribution of different emotions to various expressions. However, this time, participants could either confirm or disconfirm the correspondence between the presented and suggested expression as an indicator of the ability of tears to facilitate (or hinder) the recognition of various expressions. We also focused on reaction times (RTs), as an additional measure of the facilitation of emotion recognition. In the study by Balsters et al. (2013), participants recognized sadness significantly faster when the very briefly (50 ms) presented sad faces also had digitally added tears. We investigated whether the presence of tears affects the accuracy and speed of recognition of the expressions of not just the sadness, but also of the other five primary emotions from Study 1. Similar to Balsters et al. and in contrast to our Study 1, we did not ask the participants to choose among different expressions, but rather to indicate if a briefly (50 ms) presented picture of a human model contains a particular expression. We hypothesized that the

Table 1 Intensity reported for real and artificial faces depending on the presence of tears, for all the assigned expressions

Condition	Presented expression																				
	Disgust			Fear			Happiness			Sadness			Surprise			Anger			Neutral		
	M	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2
	Real faces																				
			.25			***.06***			.00			**.51**			***.05***			**.27**			.01
No tears	6.70	0.13		6.41	0.11		6.40	0.11		5.43	0.13		6.76	0.10		6.26	0.12		4.41	0.21	
Tears	7.20	0.11		6.64	0.11		6.46	0.14		6.36	0.12		6.92	0.10		6.76	0.11		4.32	0.17	
	Artificial faces																				
			.07			**.20**			.01			**.49**			**.16**			**.24**			.05
No tears	7.19	0.11		6.71	0.13		6.80	0.11		5.71	0.13		6.28	0.14		6.28	0.15		4.40	0.24	
Tears	7.36	0.13		7.04	0.11		6.73	0.13		6.65	0.12		6.65	0.14		6.73	0.14		4.77	0.15	

Bold letters: the effects with significance levels $p < .05$; Italics: $p < .10$; $N = 60$

Table 2 Sincerity reported for real and artificial faces depending on the presence of tears, for all the assigned expressions

Condition	Presented expression																				
	Disgust			Fear			Happiness			Sadness			Surprise			Anger			Neutral		
	M	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2
	Real faces																				
			.01			.01			**.12**			**.28**			.01			**.32**			.01
No tears	5.56	0.18		5.56	0.16		6.38	0.16		5.22	0.15		5.64	0.18		4.62	0.20		5.26	0.19	
Tears	5.65	0.18		5.46	0.14		5.80	0.20		5.80	0.16		5.73	0.14		5.39	0.20		5.39	0.18	
	Artificial faces																				
			.00			.03			.03			.07			**.13**			**.26**			.00
No tears	5.34	0.20		5.47	0.19		4.23	0.18		5.90	0.15		4.35	0.18		4.08	0.19		4.97	0.20	
Tears	5.42	0.22		5.63	0.17		4.00	0.19		6.13	0.19		4.81	0.16		4.66	0.19		4.99	0.19	

Bold letters: the effects with significance levels $p < .05$; $N = 60$

Table 3 Empathy reported for real and artificial faces depending on the presence of tears, for all the assigned expressions

Condition	Presented expression																				
	Disgust			Fear			Happiness			Sadness			Surprise			Anger			Neutral		
	M	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2	*M*	*SE*	η_p^2
	Real faces																				
			.12			.01			.00			**.38**			.04			**.35**			**.12**
No tears	4.53	0.19		4.82	0.17		5.66	0.18		4.64	0.17		4.83	0.18		3.92	0.17		3.15	0.17	
Tears	4.95	0.20		4.90	0.15		5.62	0.18		5.33	0.19		5.04	0.17		4.55	0.18		4.54	0.20	
	Artificial faces																				
			.07			**.16**			.00			**.22**			**.15**			**.25**			**.28**
No tears	4.18	0.18		4.67	0.20		3.72	0.19		5.14	0.19		3.79	0.19		3.49	0.17		3.67	0.20	
Tears	4.42	0.21		5.04	0.18		3.75	0.19		5.60	0.21		4.24	0.19		3.98	0.18		4.46	0.21	

Bold letters: the effects with significance levels $p < .05$; $N = 60$

accuracy and RTs would be affected in accordance with the pattern of responses observed in Study 1. Thus, we expected that the tears would promote faster and more accurate recognition of sad, angry, and (possibly) fearful expressions, and slower and less accurate recognition of disgust, surprise, and neutral expressions. Such results could be regarded as further support for the *ABIH* relative to the *SEH*.

Method

Participants

Forty-four students (31 females; mean age = 20.45, *SD* = 1.86) received course credits for participation. Two participants were excluded from the analysis because of corrupted data files.

Materials

A set of 48 original pictures depicting eight RF (four of each sex), each expressing six different emotions, was selected from the KDEF picture set. Compared to the pictures used in Study 1 (RF, without the pictures of neutral expressions), the set additionally included the pictures of two KDEF female (AF21, AF35) and two male (BM10, BM25) models. Tears were digitally added to each of the pictures, resulting in a final set of 96 pictures in total. In this experiment, all facial pictures were presented in full color against a black background.

Procedure

The experiment was conducted in a soundproof room, using a PC with an SVGA graphics card. Participants were seated in a chair at a distance of approximately 40 cm from a 19-in. monitor (from the forehead to the top of the screen). E-prime (2.0) software was used for the design of the experiment and stimulus presentation. In each trial, a white fixation cross was presented for 2 s against a black background. Next, one of the six emotion words was displayed for 2 s. Immediately after this, a facial picture was presented for 50 ms, followed by a 4-s response window and a black screen (2 s) as an inter-trial interval. Participants were instructed to indicate whether the depicted person was expressing the same emotion as described by the preceding word, by pressing a *yes* or *no* button on a keyboard as quickly as possible. Two-thirds of the trials had matching emotion words and emotion expressions (congruent; the correct answer was yes) and 1/3 of the trials were fillers with non-matching emotion words.

All facial stimuli were presented twice, resulting in a total number of 192 randomly presented trials, with a short break after 96 trials. A set of 4 practice trials (two congruent), all without tears, were administered before the actual experiment. Participants received feedback about their performance (“correct” or “incorrect” response) during the practice session only. The RTs were measured as the times between the onset of the picture presentation and the pressing of the response button. During the debriefing, participants were asked whether they had been aware of the presence of tears on the pictures, with none of them responding affirmatively.

Data Analysis

The accuracy was scored as the percentage of correct responses for each of the combinations of one of the six expressions and tears/no tears present. To evaluate the main and interactive effects of tears and emotion expression on the accuracy and RTs, two 2×6 repeated-measures ANOVAs were performed, with tears (tears/no-tears) and emotion (disgust, fear, happiness, sadness, surprise, and anger) as independent factors. Greenhouse–Geisser corrections were employed in order to adjust for the repeated factors with more than two levels. Only congruent trials, i.e., those for which the presented emotion label matched the presented expression were analyzed, and the analysis of RTs included only the correct responses. RTs longer than 3000 ms and faster than 400 ms (Calvo and Lundqvist 2008) were removed as outliers (2.8% of the trials).

Results and Discussion

Accuracy

A main effect of emotion was observed ($F(4,165) = 22.74$; $p < .001$; $\eta_p^2 = 0.36$), with the happy expressions recognized significantly more accurately (96%), and fearful expressions recognized less accurately (79%) than all the other expressions, although the latter recognition rate was not significantly different from those of disgust (82%) and sadness (84%), which is in line with previous research findings (e.g., Calvo and Lundqvist 2008). However, no main effect of tears, $F(1,41) = 0.74$; $p = .40$; $\eta_p^2 = 0.02$, nor an interactive effect of tears and emotion, $F(4,156) = 0.96$; $p = .43$; $\eta_p^2 = 0.02$, was observed. Thus, the presence of tears failed to influence the recognition accuracy of any of the six emotional expressions, which contradicts both the *SEH* and the *ABIH*.

Reaction Times

A main effect of emotion was observed, $F(4,161) = 54.63$; $p < .001$; $\eta_p^2 = 0.57$, with the happy expressions, expectedly, being recognized significantly faster (649 ms), and fearful expressions being recognized significantly slower (1023 ms) than all other expressions except disgust (976 ms), which is in line with the results of previous research (e.g., Calvo and Lundqvist 2008). Contrary to expectations, neither the main effect of tears, $F(1,41) = 0.11$; $p = .74$; $\eta_p^2 = 0.00$, nor the interactive effect of tears and emotion, $F(4,159) = 1.22$; $p = .30$; $\eta_p^2 = 0.03$, on RTs was observed. In other words, the failure of tears to influence the perception of any of the six expressions, as assessed by the RTs, contradicts all hypotheses. However, note that the differences in the average RTs between the tears and no tears conditions for sad (43 ms) and fearful expressions (44 ms) were substantially larger than that for sad expression (18 ms) observed in Balsters et al. study (2013). Therefore, the absence of the significant effect of tears on the RTs might, among other potential explanations, be attributed to the much larger variance in RTs found in our study. However, also note that the RTs were considerably longer, i.e., 869 compared to 568 ms in the earlier study, clearly because of the more demanding task in the current study. Means and standard errors for accuracy scores and RTs are presented in supplementary materials.

General Discussion

The goal of the current two studies was to evaluate three hypotheses about the signaling function of tears: the *sadness enhancement (SEH)*, the *intensity (IH)*, and the *appraisal/ behavioral intentions* (*ABIH*) hypothesis. To that aim, we explored the effects of tears on the recognition of expressions of disgust, fear, happiness, sadness, surprise, and anger, as well as of the neutral expression in both real, human, faces, and in artificial, computer-generated, faces. We also explored the effects of tears on the perceived intensity and sincerity of different expressions, as well as on the level of empathy towards the expressing individual. Finally, we investigated the interactive effects of tears on the speed of recognition of the same set of briefly presented RF expressions.

The percentages of misclassified expressions in non-tearful faces in both studies were relatively consistent with the results of previous studies (e.g., Calvo and Lundqvist 2008). However, tears influenced the recognition accuracy of the expressions in Study 1 only. More precisely, tears consistently decreased the recognition accuracy for disgust, surprise, and neutral expressions, while they facilitated the correct recognition of sadness and anger. Decreases in the accuracy occurred predominantly because tears resulted in more frequent misattribution of sadness and, to a lesser extent, anger to all presented expressions. These results represent both a replication of earlier findings showing that tears facilitate the perception of sadness in neutral and sad expressions (Balsters et al. 2013), and in smiling, angry, fearful, and disgusted expressions (Reed et al. 2015; Ito et al. 2019), as well as a new finding showing that tears additionally facilitate the perception of sadness in surprise expressions. The observation that tears promote the perception of anger is also in accordance with the findings of Reed et al. (2015) and, indirectly, with the findings of Ito et al. (2019). Interestingly, both the "correct" and "incorrect" attribution of sad and angry expressions in our study was facilitated primarily at the costs of the attribution of the expression of disgust. Finally, in addition to sadness and anger, the expression of fear was the only one of which the recognition accuracy did not drop at all when tears were added. In fact, tears also promoted the attribution of fear by making surprise faces (especially AF) more often labeled as fearful.

The effects of tears on the ratings of intensity, sincerity, and empathy fit the here presented findings demonstrating that tears facilitate the perception of sadness and anger. Importantly, the absence of such effects for expressions other than sadness and anger was not due to potential ceiling effects. The average intensity, sincerity, and empathy ratings for the expressions without tears across the all presented expressions were relatively similar, and were all situated between 4 and 7 on a 9-point Likert scale. When interpreting these results, it is also important to stress the critical difference between Reed et al.'s (2015) study and the present study. In Reed et al.'s study, the participants rated each particular emotion using a continuous response format, while we used forced choice procedure. Relatedly, Reed et al. (2015) explained the effects of tears on the perceived intensity irrespective of recognition accuracy. Our study analyzed the interactive effects of tears and expressions on intensity (and also sincerity and empathy) not just for all expressions, irrespective of their classification, but also for the accurately classified expressions only. The former approach allowed us to replicate the effects obtained by Reed et al. (2015), although the effects appear to have differed in magnitude (average *d*s in our and in the previous study for sadness: 0.22, 0.98, anger: 0.28, 0.60, and fear: 1.10, 0.36, respectively). This could be due to differences in stimuli between the two studies that we address below. Crucially, the latter approach allowed us to understand better the implications of the increased ratings of intensity and the other two responses. For example, the effects of tears on the perceived intensity of a neutral expression in the Reed et al. (2015) study could be explained by the fact that this expression was seen more often as sad or angry, which is precisely what we observed in our study. Tears increased the intensity of not just sadness, but also of anger, even when only accurately classified expressions were analyzed, implying that the expressions of anger themselves (and not only the attributed sadness) were perceived as more intense. Such a pattern of findings also corresponds to the current results concerning the perception of sincerity and empathy. Specifically, all the systematically observed effects were comparable to those of intensity, which prompts us to conclude that tears interact with different expressions in such a way that they promote the perception of intensity and sincerity of primarily sadness and anger, as well as empathic responses to these expressions.

In Study 2, no effects of tears on the accuracy and speed of the emotion recognition were found, contradicting the findings in support of sadness enhancement by Balsters et al. (2013), and also failing to support directly any of the current hypotheses. Study 2 was sufficiently powered for observing the effect of interest of the smallest size ($d = 0.42$) from that earlier study. Our power analysis relied on the previously reported LSD post hoc test effect sizes (three levels of the independent variable) which was comparable to the t-tests in our study (two levels of variable tears/no-tears), planned in case that a significant overall effect was observed (we adapted the minimal required number of participants to the expected overall effect of $\acute{\eta}_p^2 = 0.28$). While conducting a priori power analysis might have been appropriate, this failure to observe any effect in Study 2 may be explained by more specific factors, such as the specific nature of the very demanding task in the current study: participants had to respond to six potential expressions following very brief exposure times. Therefore, we cannot completely exclude the possibility that the current study was not sufficiently powered for the *particular* task, especially since two out of three effects of interest showed strong tendencies in the expected direction, with non-negligible effect sizes (sadness $d = 0.24$; fear $d = 0.21$). Together with the additional possibility that the earlier study was not adequately powered (30 vs. 42 participants in the current study) when it comes to the particular effect, this calls for caution when interpreting the current findings. However, the absence of the effects might also represent a clue for a more conceptual issue. Perhaps, the more sophisticated inferences about combinations of tears and facial expressions need some more time to occur (Seidel et al. 2010). We conjecture that such more complex inferences are largely responsible for the effects observed in Study 1. Of particular importance here is the fact that not a single participant in Study 2 was aware of the presence of tears in the photographs, implying that conscious awareness and more sophisticated processing, or at least a longer processing time, could conceivably allow tears to influence the responses to various expressions differently. Thus, while Study 2 provided no (relative) support for either the *SEH* or the *ABIH*, the comparison of its results with those of Study 1 has different implications for these hypotheses. The necessity of more complex inferences gives some advantage to the *ABIH*. Finally, based on the earlier study (Balsters et al. 2013), that used similarly short latencies as we do, and did observe effects, we expected the effects of tears to emerge at a pre-attentive level. However, we cannot make any firm statements about how frequently such unconscious detection did occur in our study, i.e., whether the participants did not see the tears at all. Thus, future studies could also explore the effects of slightly longer exposure times or look for some additional indicators of unconscious processing of the tears.

In general, out of the three hypotheses, the *ABIH* seems to have received the most support, in particular in Study 1. Reed et al. (2015) speculated about the possibility that tears serve as a signal enhancing the perception of sadness across approach related emotional expressions. However, while tears indeed facilitate the perception of sadness (the overlapping part of the *SEH* and *ABIH*), the present results clearly demonstrate that tears also increase the intensity and sincerity (as well as the experienced empathy), and they result in both correct and incorrect labeling of emotions other than that of sadness to different expressions, in particular, anger, and, to lesser extent, fear. The current findings thus stress the need for an update of the conclusion by Ito et al. (2019) and Provine et al. (2009), who stressed the *sadness enhancement* role of tears. Instead, the overall pattern of findings from the present and two previous studies (Ito et al. 2019; Reed et al. 2015) appeared to provide most support for the *ABIH*. Finally, the results of the current and the previous studies appear to be difficult to reconcile with a simple version of the *IH*, since tears increased the intensity (and related responses) of only some (i.e., sadness and anger; providing potential support for the *IH*) but not all expressions. Thus, the *IH* would need to be amended to account for the findings that tears might affect different emotions differently.

According to the *ABIH*, tears communicate information about the presence of helplessness-related appraisal and corresponding behavioral intentions rather than any specific emotion (see Gračanin et al. 2018; Vingerhoets 2013). This also assumes the passivity of the crier and the absence of any behavioral intentions. Crucially, the overlap between appraisals/intentions signaled by tears and those signaled by muscular emotional expressions might result in a bias towards the perception of certain expressions. Accordingly, the results of Study 1 show that tears facilitate both correct recognition, as well as the misattribution of the presence of those expressions that reflect appraisal processes associated with helplessness (sadness, anger, and fear; see, e.g., Ellsworth and Smith 1988), whereas they hinder the recognition of other emotions. Sadness, anger, and fear are compatible with such appraisals (e.g., "I am not the one who can solve this situation"), or action tendencies (e.g., being receptive to comfort from others) to a different extent, ranging from high to low, respectively, and, consequently, they should differently facilitate corresponding inferences about the presence of these expressions. Substantial differences in the magnitude of the effects of tears on the perception of these three expressions observed in Study 1 support that aspect of the *ABIH*. Specifically, sadness is by definition associated with helplessness since it typically includes an appraisal of low situation controllability (Ellsworth and Smith 1988). Functional responses to a sadness expression may include the provision of support and nurturance, which fits the passive stance typical of this emotion (Barr-Zisowitz 2000). In contrast, anger is accompanied with appraisals of helplessness only in certain situations (e.g., in case of the phenomenon known as "powerless anger" or frustration; or in the case of *protest tears*; Nelson 2005; Vingerhoets 2013). Finally, fear that occurs in uncontrollable situations (Öhman 2010), may be signaled to others who can provide help, although active flight or fight reactions may be more common. This could explain the small effects of tears in case of fear. However, the proposed idea about appraisal processes revolving around helplessness and low coping potential is undoubtedly not the only possible or the most useful account of adaptive cognitive processes that precede or accompany crying. A more fine-grained analysis might focus on dimensions such as goal/need significance and coping potential, as well as novelty (Scherer et al. 2017), or urgency (Scherer 1984).

An interesting question is why tears systematically increase the perception of specific expressions at the cost of the recognition of the expression of disgust. The answer might be found in the proposed attachment and distance-regulation functions of tears. While the expression of (social) disgust implies a readiness to avoid the target of the signal, tears promote a connection between people and they facilitate social bonding (Gračanin et al. 2018). Similar to contempt, the expression of disgust is "reserved" for individuals that one can better avoid than to seek their help (sad and fearful expression) or even to confront (angry expression). Disgust focuses on the evilness of a person instead of a specific action, while anger is more often a direct response to an inappropriate action (Fischer and Giner-Sorolla 2016; Ortony et al. 1988). Finally, even the expression of anger can fulfill the function of promotion of helping and nurturing responses, especially when combined with protest crying ("I am angry at you because you want to leave me"). In contrast, the expression of disgust more likely sends a message that one does not tolerate the other individual's proximity.

A simple mechanism through which tears might signal specific appraisal/intentions concerns the possibility that tears simply draw attention to the upper face area, and correspondingly, distract the observer's attention away from other facial areas, thus influencing the perception of a given expression. A careful analysis of the action units that are activated during the expression of six distinct emotions (Ekman and Friesen 1978; Pantic and Rothkrantz 2000; Rigoulot and Pell 2015) suggests that ignoring the lower part of the face and relying more on the eye area could result in systematic biases in emotion recognition. For example, three action units situated within the eye area are essential for expressing sadness (AU1, AU4, AU7) while the expression of disgust, whose perception was decreased by the presence of tears to the greatest extent, depends mostly on action units that are situated outside of the eyes area (AU9, AU15, AU16; AU17; note that AU9 – the *nose wrinkler* – does affect the area around the eyes, but to a lesser extent). The same holds for the comparison of the expression of disgust and that of anger (AU4, AU5, AU7, all in the eye area), which may also represent a proximate explanation for the large increases in assignments of anger to disgusted expressions to which tears were added. Finally, it has been suggested that there are cultural differences between the Western observers, who tend to fixate their gaze on the eyes and mouth, and Eastern observers, who focus on the nose (Blais et al. 2008), which prompts an interesting research question whether tears interact with facial expressions in the same way across different cultures.

Strengths and Limitations

The current study used identical static images for tears and no-tears conditions, with the only difference being the presence of digitally added tears. Reed et al. (2015) video recorded an actress in two similar situations, in which eye drops were added on the actress' face while she expressed targeted emotions. While the latter approach has important advantages in terms of the stimuli's ecological validity (dynamic vs. static facial expressions), the expressions with and without tears in their study could not be completely identical. Given the smaller number of expressing models (1 vs. 4), presenting only a female model, and the overall amount of exposure to different stimuli of the same category (1 vs. 8) in the Reed et al. study, this makes our stimulus presentation arguably somewhat more generalizable. Further, because it is possible that posed expressions produce different effects than non-posed expressions, we additionally exposed participants to the AF. Moreover, the AF allowed for better control of intensity across exemplars, gender, and maybe also expression categories. Finally, previous studies have shown that AF may evoke similar responses as RF (e.g., Todorov et al. 2009), although it was not known whether these effects would work for tears. Therefore, additional testing of the current hypotheses by using avatars has a threefold benefit. First, it allowed us to evaluate our hypotheses across different methodologies. Second, it helped us to exclude the potentially confounding influence of human posed expressions. Finally, the ability of tears to influence the recognition of emotions in non-human faces likewise points to the strength of this signal.

Most problematic of the current research is the inability of Study 2 to (conceptually) replicate the findings from Study 1. In addition to evaluating the explanation based on the potential difference between two levels (i.e., pre-attentive vs. more complex) of processing of emotional expressions (Seidel et al. 2010), future studies should certainly also apply less demanding tasks for the participants. The cognitive load required for responding to six potential expressions following very brief exposure times might overshadow any subtle effects of tears. An additional significant limitation of the present two studies is that we employed prototypical expressions of high intensity, which are relatively rare. While such types of stimuli represented a standard in previous studies (e.g., Carroll and Russell 1996), future studies should focus on expressions of mild to moderate intensity. The intensity could be varied more systematically by the use of AF, which were shown to represent valid stimuli in this study. Next, we may also consider the inclusion of other relevant expressions, such as guilt, embarrassment, submission, and pride. Further, subjective feelings (e.g., happiness) that co-occur with emotional expressions of the opposite valence (e.g., pain or sadness) are typically accompanied with tears (Aragón and Bargh 2018). Accordingly, sad expressions with tears in our study could also imply the observers' attribution of happy feelings. However, our findings do not support that claim. Likely, for such attributions to occur, certain contextual information (e.g., "the depicted person just won the tournament") is needed, as context plays a key role in the attribution of emotion in others (Carroll and Russell 1996). Therefore, future research on the interaction between muscular facial expressions and tears might benefit from providing contextual information. In addition, a more fine-grained analysis of responses towards individual AUs and their intensity could help to shed further light on the intensity and sadness enhancement hypotheses. While the KDEF stimulus set has been widely used for the study of basic emotions, it is possible that the intensity of individual AUs in this set may differ from other materials, such as the images employed by Reed et al. (2015). Here, a systematic variation of individual AU intensities might help to provide more favorable conditions for the evaluation of the *IH* and *SEH*. Furthermore, such an approach could also examine partial expressions that may reflect more common and naturalistic expressions. Thus, it might help to overcome the predominant focus on the Basic Emotion Theory in this field, which has been severely challenged in recent years (Küster et al. 2020). Importantly, future research should focus directly on the ability of tears to moderate the effects of the specific appraisals (helplessness, perceived need of social support), and related intentions on the emotion recognition accuracy and other relevant (e.g., empathic) reactions. Also, instead of dealing with discrete emotions categories, research could benefit from carefully assessing appraisals and intentions assigned to crying and non-crying faces (see Scherer et al. 2017), which would represent a further validation of the *ABIH* that gained most support in the current study.

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