

Research



**Cite this article:** Mauersberger H, Kastendieck T, Hetmann A, Schöll A, Hess U. 2022 The different shades of laughter: when do we laugh and when do we mimic other's laughter? *Phil. Trans. R. Soc. B* **377**: 20210188. <https://doi.org/10.1098/rstb.2021.0188>

Received: 14 October 2021

Accepted: 7 January 2022

One contribution of 17 to a theme issue 'Cracking the laugh code: laughter through the lens of biology, psychology and neuroscience'.

**Subject Areas:**

behaviour, cognition

**Keywords:**

laughter, schadenfreude, facial expression, facial mimicry

**Author for correspondence:**

Heidi Mauersberger

e-mail: [heidi.mauersberger@hu-berlin.de](mailto:heidi.mauersberger@hu-berlin.de)

Electronic supplementary material is available online at <https://doi.org/10.6084/m9.figshare.c.6125817>.

# The different shades of laughter: when do we laugh and when do we mimic other's laughter?

Heidi Mauersberger, Till Kastendieck, Annika Hetmann, Anja Schöll and Ursula Hess

Department of Psychology, Humboldt University of Berlin, 10099 Berlin, Germany

HM, 0000-0001-6743-8654; TK, 0000-0001-6675-0144; UH, 0000-0002-6793-7282

Laughter is an ambiguous phenomenon in response to both positive and negative events and a social signal that coordinates social interactions. We assessed (i) who laughs and why, and (ii) if the type of laughter and whether the observer approves of it impact on facial mimicry as a proxy for shared laughter. For this, 329 participants watched funny, schadenfreude and disgusting scenes and then saw individuals who purportedly reacted to each scene while participants' facial expressions were recorded and analysed. Participants laughed more in response to funny than in response to schadenfreude scenes and least in response to disgust scenes, and laughter within each scene could be explained both by situational perceptions of the scenes as well as by individual differences. Furthermore, others' laughter in response to funny scenes was perceived as more appropriate, elicited more closeness and more laughter mimicry than others' laughter in response to schadenfreude and especially in response to disgust scenes. Appropriateness and closeness as well as individual differences could explain laughter mimicry within each scene. This is in line with the notion that laughter is not *per se* an affiliative signal and that different types of laughter have distinct social implications.

This article is part of the theme issue 'Cracking the laugh code: laughter through the lens of biology, psychology and neuroscience'.

## 1. Introduction

Laughter is a pervasive and highly contagious behaviour that is typically shown in enjoyable and friendly interactions [1]. Similar to non-human play vocalizations, it fosters social bonding, as it is linked to positive emotions such as joy that function to signal positive intents [2]. Yet, laughter can also be malicious, especially when related to ridicule and schadenfreude (defined as a positive feeling in reaction to the misfortune of others), which is often accompanied by laughter [3,4] and shown towards those whom we do not like [5].

In the present context, we focused on the social perception of laughter in response to an external event that can be considered funny (both in a benign and malicious way). Specifically, the present research aimed to better understand both when laughter takes place and how laughter is perceived and reacted to by others as a function of the context in which laughter occurs and the observers' own perception of the laughter stimulus. In particular, we focused on the notion that laughing together fosters affiliation [6]. To approach this phenomenon empirically, we assessed when participants mimic the laughter of others as a proxy for laughing together.

### (a) The social functions of laughter

Laughter is generally considered to signal affiliation or cooperative intent based on evolutionary considerations [2,7]. Laughter is considered a homologue of non-human play vocalizations [2], that is, sounds emitted by young animals

during play—which often includes chases and playful aggression—to signal that this is not a real fight but indeed play. Thus, these vocalizations signal that the situation is not threatening but rather affiliative. Laughing together is therefore linked to bonding.

Next to the ‘play’ aspect of laughter, bonding can also occur through the more communicative function of laughter. Specifically, laughter in response to humour can serve as a means of social assortment [8]. That is, interaction partners can present ideas in a ‘humorous’ way to assess the reactions of others, and the shared laughter indicates shared beliefs or values. As such, shared laughter can be a marker of an ‘in-group’ affiliation.

### (b) Why do people laugh?

Laughter is most commonly shown in interactions, and in fact, much laughter comes from the speaker in reaction to their own comment [1]. When laughing in response to an external event, people generally report that they laugh because what happened was funny or humorous [1]. But what are the reasons that explain *why* people find something funny? Why, for instance, do we think it is funny when a mouse chases a cat? The most likely answer to this question is that we perceive this behaviour as incongruent to our expectations and this perceived incongruity results in feelings of amusement and hence laughter [9]. A simple violation, however, may not be enough to evoke feelings of funniness. The observed event must be at least of moderate intensity to be funny (yet too intense norm violations may be also threatening, reducing funniness perceptions, [7]; see below) [10]. Furthermore, we need to be able to relate to the situation to understand that something is absurd. In this sense, shared laughter is linked to shared values and shared cultural understanding as a basis for a shared sense of the absurd (see above). Members of the ingroup ‘get’ the joke, whereas members of the outgroup do not [8]. This notion is especially relevant when we consider shared or mimicked laughter in the context of *schadenfreude* and disgust.

### (c) Laughter in *schadenfreude* and disgust

Laughter may not only result from incongruity but also from feelings of triumph and superiority over another person [9], an emotional reaction called *schadenfreude*. *Schadenfreude* is the positive feeling in reaction to the misfortune of others [4]. Despite being a common reaction, it has been considered morally questionable because *schadenfreude* is incongruent with compassion [11]. Hence, laughter as an expression of *schadenfreude* may be perceived as more inappropriate than laughter to incongruent, light-hearted and non-serious ‘genuine funny’ situations. Yet, what is considered funny depends on both the observer and the relationship between the observer and the target of laughter.

*Schadenfreude* is felt more commonly towards those we do not like or feel envious of [5,12]. It follows specifically if the observer feels that the person experiencing the misfortune is not worthy of something they have and in this sense serves to elevate the self in comparison [11]. Perceived deservingness plays a major role here. The person experiencing the misfortune does—in the observer’s opinion—deserve a penalty (i.e. the misfortune they experience), because this person has done something unjust or morally wrong, possibly even harming another human or animal. Hence, to

restore the balance of justice, the negative action should lead to a negative outcome [4,13]. Notably, the observer considers the event funny and the laughter associated with *schadenfreude* is predominantly Duchenne laughter that is not readily distinguishable from laughter at other funny events [3].

Laughing at disgusting stimuli has been interpreted similarly. Overall, disgusting events should be perceived less humorous and lead to even less laughter than ‘*schadenfreude*’ events. This may be because laughter in disgust situations may generally seem inappropriate and morally questionable. Yet, a disgusting experience is debasing and this debasement can be considered funny if experienced by a disliked other [14]. McDougall [15] suggested that laughter allows people to distance themselves from events that demand too much empathy. This is especially the case when these events befall disliked others who deserve the circumstances they find themselves in. As such, we would expect that *schadenfreude* or disgusting events would be considered funny and result in laughter when the observer considers the misfortune or debasement as deserved. Whether others join into laughter again depends on a shared perspective. If they also feel that the victim of the misfortune deserved the misfortune, then laughter should seem appropriate and hence be mimicked.

### (d) Individual differences

Individuals differ in their reaction to others’ misfortunes [16]. Some enjoy watching harm done, whereas others may find it repulsive. Latest attempts to measure trait *schadenfreude* differentiate between a ‘benign’ form of *schadenfreude*, where individuals report enjoying small almost harmless accidents, and a ‘malicious’ form of *schadenfreude*, where individuals report enjoying somewhat more harmful accidents. This latter form of *schadenfreude* is more closely related to sadism, which, however, should still be differentiated from *schadenfreude*. The person experiencing sadistic pleasure intentionally and *actively* hurts someone who may *not deserve* this harm that they have to endure [11]. The important difference is that *schadenfreude* is restricted to pleasure at a misfortune that happens without the involvement of the expresser, whereas sadism includes the willingness to do harm. Another crucial difference between *schadenfreude* and sadism according to Ben-Ze’ev [11] is that for *schadenfreude* to occur, the misfortune should not be too extreme or serious but rather moderate or minor [16].

Yet, there is a conceptual overlap between the definition of benign *schadenfreude* (BS) and what incongruity theory predicts for ‘genuinely funny’ situations: a benign (i.e. acceptable/harmless) violation of an expectation or a norm takes place. Accordingly, incongruity theory is also sometimes called ‘benign violation theory’ [10]. Hence, BS may not only predict which individuals are attracted to *schadenfreude* events, but also which individuals react with laughter to ‘normatively’ funny events due to the ‘unexpected paradox’ component that both events often have in common.

### (e) The role of facial mimicry in social affiliation

Most of the research discussed above considers laughter from the perspective of the encoder. That is, it focuses on when people laugh, and the effects of laughter on the person who laughs. Yet, as noted above, laughter has important social functions—in particular, for bonding and affiliation—and as

such, it is important to study the interaction partner's reactions to laughter. Specifically, not all laughter is considered appropriate. Schadenfreude and ridicule in particular are often considered malicious behaviour and hence inappropriate [12].

Behaviour that is perceived as appropriate leads to more perceived interpersonal closeness (IC) between observer and expresser, which, in turn, moderates the imitation of this behaviour in the form of mimicry [17]. Specifically, Kastendieck *et al.* [17] tested and confirmed a serial mediation model according to which the context, in which smiles and sad expressions were shown, affected the perceived appropriateness of these expressions, which, in turn, affected the perceived closeness of expresser and observer. Closeness then affected the degree to which smiles (but not sad expressions) were mimicked. The authors explain this with the notion that smiles are more ambiguous in their meaning and require some indication that the smile is indeed a positive signal before they will be mimicked. Sadness expressions, by contrast, have a strong appeal for empathy [18] and hence are less ambiguous in meaning. Whether laughter will be mimicked, should therefore depend on the perceived appropriateness of the observed behaviour and the perceived closeness of expresser and observer. Kastendieck *et al.*'s [17] study was based on the mimicry as social regulator view [19,20], which considers mimicry a social act that is informed by the social meaning of the mimicked expression.

Another view of mimicry is based on research that focuses on the neurological basis of embodiment processes, which from this perspective includes mimicry [21]. The basic notion is that when people make social judgements, they simulate relevant aspects of the stimulus in a form of embodied cognition [21]. From this perspective, people simulate the expression in the sensorimotor cortex when judging emotion expressions. The resulting motor output would then be (facial) mimicry (for more detail, see [22]). Because of a presumed direct link to mirror neurons, what is mimicked has to be the specific motor movement that was observed. The interaction of this bottom-up process with the top-down process of interest in this research remains to be established [20]. In the present context, we are assessing mimicry to expressions that are morphologically identical but differ in meaning. That is, the specific muscle movements that are mirrored or simulated would be the same but their social and interactional consequences are different. We predict, based on the mimicry as social regulator view, that overt mimicry will be predicated by the meaning of the expression. This does not necessarily preclude mirroring processes that do not result in overt mimicry [23].

## 2. The present study

The present study aimed to better understand why people laugh and how other's laughter is perceived and reacted to as a function of context. For this, participants watched scenes that elicited either amusement, schadenfreude or disgust, while their own expressive behaviour was recorded. Following each scene, they saw three 'reactions' (videos showing individuals who purportedly reacted with either laughter, smiling or a neutral expression, see below). Participants were filmed throughout and facial reactions to the

scenes and facial mimicry to the expresser were assessed. In particular, we assessed whether participants showed enjoyment smiles or Duchenne laughter in response to the scenes or in response to watching others react to the scenes.

### (a) Hypotheses

We predicted that

- participants laugh less in response to a schadenfreude scene compared to a funny scene and the least in response to a disgust scene;
- individual differences in trait schadenfreude and sadism as well as scene intensity (SI) and perceived deservingness explain funniness and repulsiveness ratings as well as relatedness to the scene, which, in turn, predict own laughter reactions;
- perceived laughter appropriateness, perceived IC and laughter mimicry are reduced after a schadenfreude scene compared to a funny scene and more so in response to a disgust scene;
- individual differences in schadenfreude and sadism as well as perceived laughter appropriateness predict perceived IC, which, in turn, predicts laughter mimicry.

## 3. Method

### (a) Participants

For the planned analyses, there are currently no satisfactory power analysis tools. We aimed for a sample size of 250–300 participants. This sample size should allow investigation of the relationships between individual differences and facial behaviour during an experimental session [24]. The final sample consisted of data from 329 participants (203 women and eight individuals identifying as gender-diverse) with a mean age of 35.4 (s.d. = 14.5). Participants received £8.33/hour for their participation, which is considered as *good* payment in Prolific UK. On average, the task took about 28 min and 32.5 s (advertised as a 30 min task). For details on data exclusion, see the electronic supplementary materials part A.

### (b) Stimulus material

#### (i) Scenes

Scenes were drawn from a pool of over 1000 short (5–15 s long) amateur video clips from web video platforms such as Instagram, YouTube, 9gag or TikTok. Search words included 'slapstick', 'schadenfreude', 'instant karma', 'fail', etc.

*Funny scenes* were chosen on the basis of incongruity theory. That is, they had to depict a paradox or incongruous action or situation. Protagonists should act in a way that would be perceived as strange, unexpected or unusual. For example, in one scene, a mouse chases a cat. For this category, we only selected videos that entailed positive, light-hearted and non-serious situations.

*Schadenfreude scenes* were chosen on the basis of superiority theory, which considers humour as a feeling of triumph over others when an unfortunate event occurs to them. We selected scenes in which a protagonist experiences a failure or misfortune they deserve albeit without being seriously harmed. For instance, one of our scenes shows a man who intends to push another man into the water, but instead stumbles and falls in himself.

*Disgust scenes* were chosen to reflect disgusting events, which were not designed to be funny. Here, we chose mildly repulsive videos, as extremely negatively valenced stimuli may raise ethical concerns and also make a laughter response less plausible.

An example of a scene suitable for this category shows a man who eats a bug.

*Final selection.* A preliminary set of 24 scenes that passed all the aforementioned criteria was rated by an independent sample of 30 participants with regard to their funniness (funny and schadenfreude scenes), repulsiveness (disgust scenes) and the protagonists' deservingness (schadenfreude scenes). The final scene stimuli (six per category) had an average length of 10.7 s. For more details see the electronic supplementary materials part B.

## (ii) Reactions to scenes

'Reactions' were selected and extracted from the multi-modal database of laughter during dyadic interactions [25]. The final pool of reactions videos consisted of 18 actors (nine female/nine male) for whom we could identify at least one genuine laughter, smile and neutral expression of similar length (the latter two expressions served as distractor items to create a more believable set of reactions to the scenes, as it is more likely that scenes elicit a range of reactions (i.e. not everybody may laugh at every stimulus)). The final reaction stimuli had an average length of 4.63 s.

## (c) Procedure

Participants were informed about the content and length of the task. Furthermore, they were informed that participation in the experiment was only possible if they had a webcam-enabled computer/laptop and agreed to a webcam recording of their face during the experiment. Informed consent included standard details on compensation, confidentiality and contact information as well as detailed information on (video) data storage and processing. Participants who gave informed consent were instructed to set up their webcam to allow recording, to arrange sufficient lighting and to refrain from eating or covering their face during the experiment. Participants then provided general socio-demographic information and subsequently saw the scene and reaction stimuli while their facial activity was recorded.

After a practice trial (one funny scene that did not belong to the final selection of funny scenes) followed by three reaction stimuli (two laughter, one neutral reaction from three actors who were not used for the experimental trials), participants saw a random selection of two schadenfreude, two funny and two disgust scenes drawn from the pool of 18 (six each) scenes. Each scene was followed by three actors reacting to the scenes (two laughter, one smiling or neutral reaction in random order; see above). Each participant saw each actor only once. Whether an actor was displayed as laughing, with a neutral or smiling facial expression was randomized across participants. Prior to the presentation of each stimulus (scene and reaction), a fixation cross of 1.5 s was shown, which served as running baseline for the facial behaviour analysis data (see below). At the end of the experiment, participants completed two questions asking for technical issues and were then given the opportunity to opt out by asking for their videos to be erased (no participant used this option). Participants were informed about the purpose of the experiment, thanked for their participation and redirected to Prolific in order to obtain their payment.

The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the Department's Ethics committee. Participants were aware that they had the right to discontinue participation at any time and that their responses were confidential. The study was pre-registered prior to data collection (see <https://osf.io/sge8n/>).

## (d) Dependent measures

### (i) Self-report

Following each reaction video, participants rated the emotion expressed on an emotion profile comprised the scales

amusement, schadenfreude, disgust, contempt, fear, anger and surprise and indicated how appropriate they perceived the expression to be on a slider ranging from 0 (not at all) to 100 (very intensely). Furthermore, they rated how close they felt to the expresser using the Inclusion of Other in the Self-scale (IOS; [21]). Following the three 'reactions' to one scene, participants were asked to indicate whether they could relate to the event displayed in the scene (an adapted IOS [26]) as well as how funny, repulsive and intense they perceived the scene, whether the protagonist deserved what had happened to them on a slider ranging from 0 (not at all) to 100 (very intensely) and, finally, who the protagonist in the scene was to assess whether participants had indeed watched the scene.

### (ii) Individual difference measures

At the end of the experiment, participants completed three questionnaires: Schadenfreude trait [16], Dark Tetrad [27], and Toronto Empathy Questionnaire [28].<sup>1</sup>

## (e) Facial behaviour analysis

The uploaded videos were analysed using the open-source facial behaviour analysis toolkit OpenFace 2.0 [29]. OpenFace analyses facial activity in terms of facial action units as classified in the Facial Action Coding System [30]. Frames with detection confidence lower than 75% were excluded [31]. Five additional participants had to be excluded from the 'own laughter' dataset (comprising participants' reactions to the scene videos) and one additional participant had to be excluded from the 'laughter mimicry' dataset (comprising participants' reactions to the reaction videos), as either no corresponding videos were uploaded or OpenFace could not identify facial expressions in any of the uploaded videos.

### (i) Facial activity data preparation

Based on the OpenFace data, own laughter and laughter mimicry were assessed using facial action units AU4 (eyebrows drawn together), AU6 (wrinkles in the corner of the eyes) and AU12 (lip corners pulled up). Scores were baseline-corrected and then a positive pattern score was computed, as described by Hess *et al.* [32] for facial electromyography (EMG), which indicates the contrast between the average activity of zygomaticus major (or AU12 in OpenFace) and orbicularis oculi lateralis (AU6) minus the activity of corrugator supercilii (AU4). We excluded trials during which participants reported to have technical issues or when more than two thirds of the baseline or trial frames were missing. This reduced the sample size to 317 for the 'own laughter' dataset and to 326 for the 'laughter mimicry' dataset. Furthermore, if data of more than four scenes or 12 reactions were unusable or missing, we excluded the participant from the corresponding dataset, reducing the sample size to 309 and 315, respectively. Frames of the uploaded videos recorded during scene videos were divided into four segments: beginning, middle, climax and end. Frames of the uploaded videos recorded during reaction videos were binned into 500 ms intervals. We identified and excluded univariate outliers by visual inspection of the cluster of points within a violin plot. Datasets and a detailed R Markdown HTML will be provided at OSF (<https://osf.io/sge8n/>).

## 4. Results

### (a) Manipulation check

We used linear mixed modelling (LMM) to assess whether our scenes had the intended effects with regard to their funniness, deservingness and repulsiveness ratings (for details of these

**Table 1.** LMM results. CI, confidence interval; LL, lower limit; UL, upper limit; fun, funny scene; sch, schadenfreude scene; dis, disgust scene; seg, time segment; tme, time period.

effect	estimate	95% CI		t-val.	p
		LL	UL		
<b>own laughter</b>					
(intercept)	0.13	0.09	0.16	7.53	<0.001
sch-fun	-0.25	-0.28	-0.22	-15.0	<0.001
dis-sch	-0.23	-0.26	-0.20	-13.8	<0.001
seg	0.10	0.08	0.11	16.0	<0.001
sch-fun * seg	0.02	-0.001	0.05	1.64	0.10
dis-sch * seg	-0.13	-0.16	-0.10	-8.82	<0.001
<b>appropriateness</b>					
(intercept)	53.7	52.2	55.3	67.5	<0.001
sch-fun	-6.05	-7.75	-4.34	-6.96	<0.001
dis-sch	-38.9	-40.6	-37.2	-44.7	<0.001
<b>interpersonal closeness</b>					
(intercept)	2.46	2.35	2.57	43.8	<0.001
sch-fun	-0.11	-0.205	-0.022	-2.43	0.015
dis-sch	-1.43	-1.52	-1.34	-30.5	<0.001
<b>laughter mimicry</b>					
(intercept)	0.077	0.054	0.10	6.44	<0.001
sch-fun	-0.055	-0.065	-0.044	-10.4	<0.001
dis-sch	-0.12	-0.13	-0.11	-23.4	<0.001
tme	0.008	0.007	0.009	13.1	<0.001
sch-fun * tme	-0.001	-0.004	0.002	-0.73	0.46
dis-sch * tme	-0.006	-0.009	-0.003	-3.84	<0.001

analyses, see electronic supplementary materials part D). The analyses confirmed that the scenes were perceived as intended.

### (b) Own facial reactions to scenes

As predicted, a LMM analysis with the fixed factors *scene* and *time segment* revealed a clear ranking with the most intense positive expressions for funny scenes, followed by schadenfreude scenes and then disgust scenes. Furthermore, the difference between schadenfreude and disgust scenes increased over time (table 1 and figure 1a).<sup>2</sup>

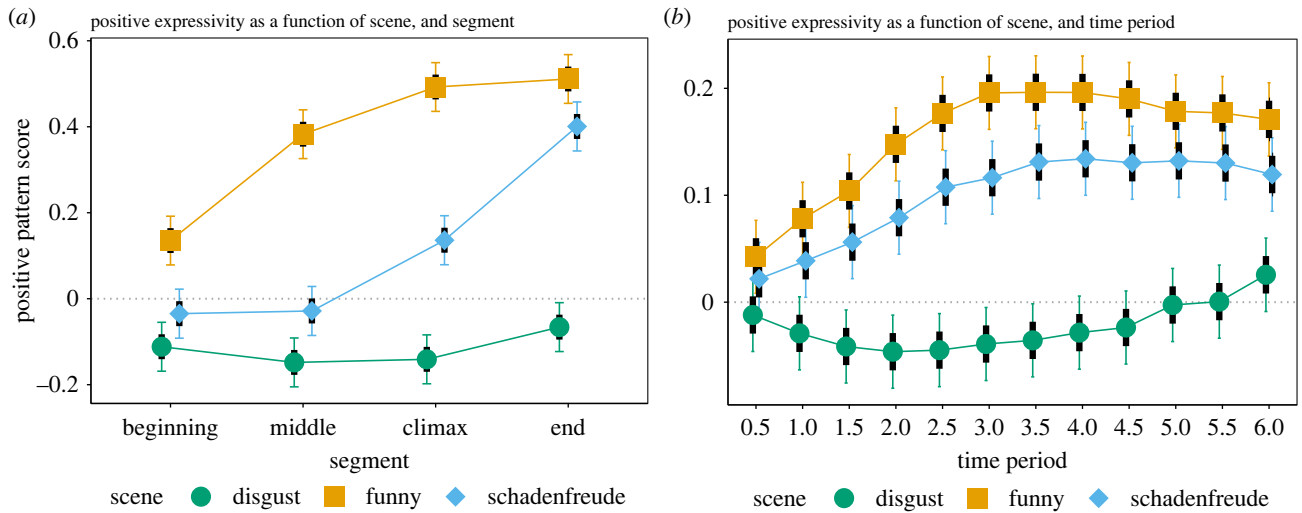
To explain who laughs and under which circumstances, we build multi-level mediation models [33] for each type of scene separately.<sup>3</sup> We used the *RMeditation* package [34] to test the indirect effects.

Benign schadenfreude (BS) and malicious schadenfreude (MS) (and sadism for disgust scenes) as well as the intensity ratings for the scene (SI) and deservingness (the latter only for schadenfreude and disgust scenes) were external predictor variables. How well participants could relate to the scene (scene relatedness (SR)), funniness ratings and repulsiveness ratings (the latter only for schadenfreude and disgust scenes) were the mediator variables, and own laughter (i.e. a positive facial expression in response to the scene) the outcome variable. Predictors and mediators were only retained in the model if they explained significant variance (in the mediator or/and the outcome variable, respectively).<sup>4</sup>

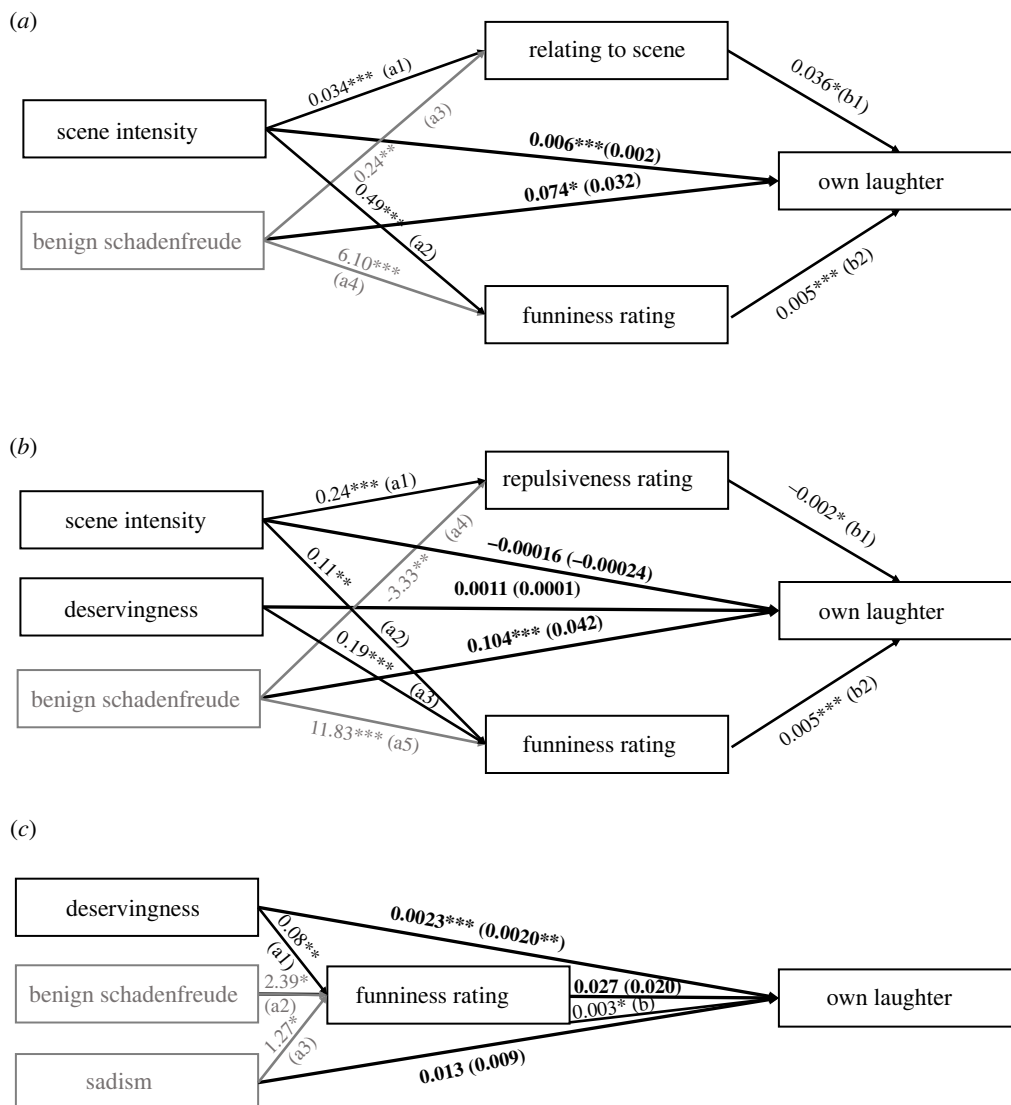
The final models for each scene are displayed in figure 2. Table 2 lists the significant indirect effects. For funny scenes (figure 2a), SR and funniness ratings emerged as mediators. SI and BS predicted more laughter via higher SR and higher funniness ratings. For schadenfreude scenes (figure 2b), repulsiveness ratings and funniness ratings emerged as mediators. SI and BS predicted more laughter via higher funniness ratings but, at the same time, less laughter via higher repulsiveness ratings; deservingness predicted more laughter via higher funniness ratings. Finally, for disgust scenes (figure 2c), only funniness ratings emerged as mediator. Deservingness, BS and sadism predicted more laughter via higher funniness ratings. In sum, as expected, BS predicted perceived funniness and own laughter not only for schadenfreude scenes but also for funny and disgust scenes. This suggests that indeed incongruity and benign mishaps share some levels of unexpectedness which is appealing to those who score high on BS. Given that our disgust scenes were relatively mild, we also observed some overlap here. At the same time, sadism scores also predicted funniness ratings and own laughter for disgust scenes.

### (c) Facial mimicry: reactions to others' laughter reactions

As predicted, LMM analyses with the fixed factor *scene* and the covariate *time period* (for laughter mimicry) revealed a clear ranking with highest perceived appropriateness and IC ratings



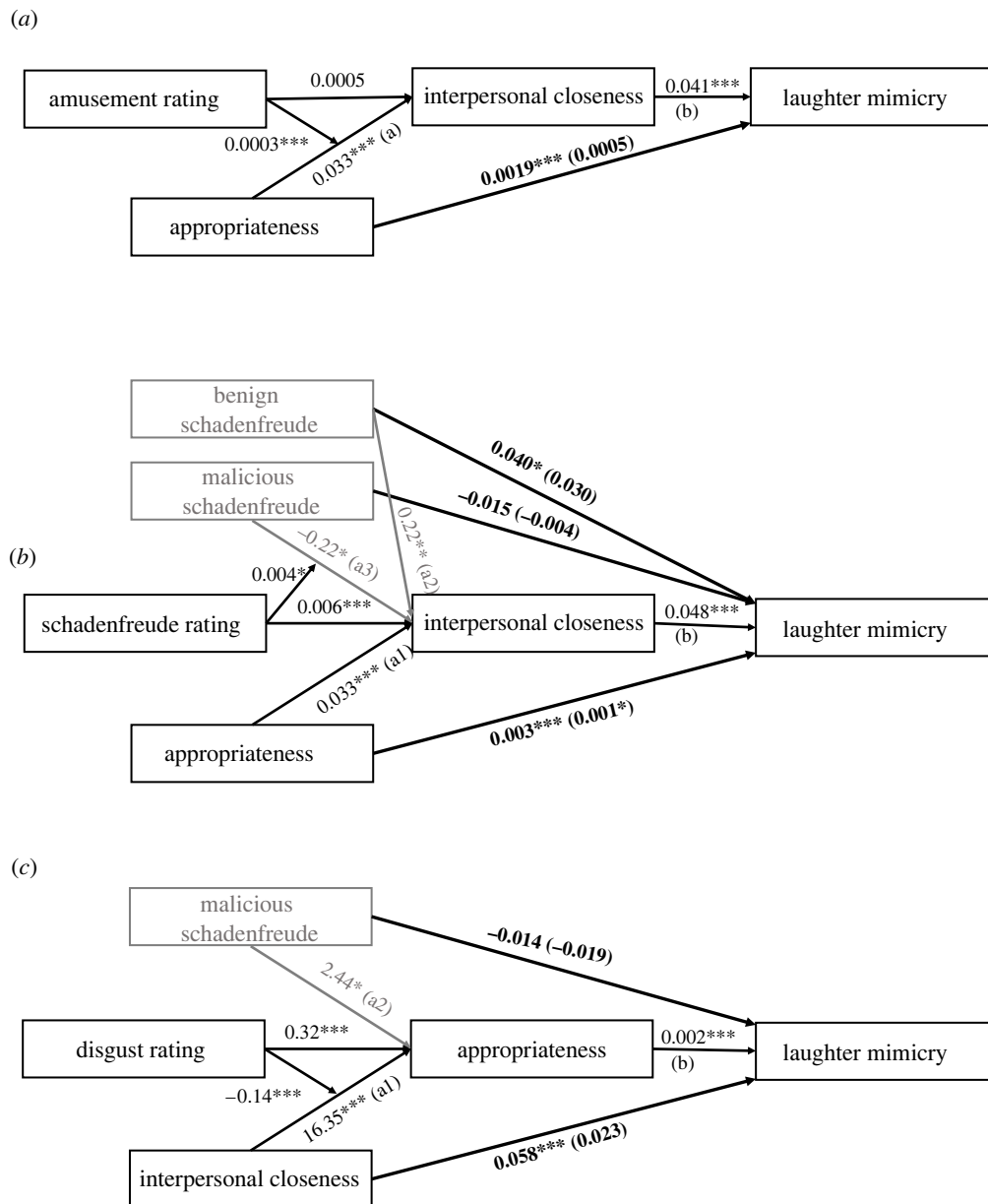
**Figure 1.** Own laughter (a) and laughter mimicry (b) as a function of scene across time. Coloured bars represent 95% confidence intervals and black bars represent standard errors. (Online version in colour.)



**Figure 2.** Mediation models for own laughter reactions. (a) Own laughter during funny scene; (b) own laughter during schadenfreude scene; (c) own laughter during disgust scene. Unstandardized coefficients for each path. Indirect effects (a, b) in black for scene perception and grey for individual differences. Total effects in bold and direct effects in bold and in parentheses. \* $p \leq 0.05$ ; \*\* $p \leq 0.01$ ; \*\*\* $p \leq 0.001$ .

as well as the most intense positive expressions for laughter reactions to funny scenes, followed by schadenfreude scenes and then disgust scenes. Furthermore, the difference between

positive expressions to laughter reactions during schadenfreude and disgust scenes increased over time (table 1 and figure 1b, as well as electronic supplementary materials part D).



**Figure 3.** Mediation models for laughter mimicry. (a) Laughter mimicry during funny scene; (b) laughter mimicry during schadenfreude scene; (c) laughter mimicry during disgust scene. Unstandardized coefficients for each path. Indirect effects (a, b) in black for the perception of others reactions and grey for individual differences. Total effects in bold and direct effects in bold and in parentheses. \* $p \leq 0.05$ ; \*\* $p \leq 0.01$ ; \*\*\* $p \leq 0.001$ .

We further conducted mediation analyses following the procedure described above. BS and MS (and sadism for disgust scenes) as well as ratings of appropriateness and amusement, schadenfreude and disgust were external predictor variables. IC was the mediator and laughter mimicry (i.e. a positive facial expression in response to others' laughter) the outcome variable. Again, predictors and mediators were only retained in the model if they explained significant variance (see endnote 3). For the disgust scenes, IC had to be removed from the model as mediator variable and was replaced by appropriateness. The final models for each scene are displayed in figure 3. Table 2 lists the significant indirect effects. For funny scenes (figure 3a), appropriateness predicted more laughter mimicry via higher IC. Furthermore, there was an interaction between appropriateness and amusement ratings: the more amusement participants perceived in the laughing other, the higher was the indirect effect. For schadenfreude scenes (figure 3b), appropriateness and BS predicted more laughter mimicry via IC whereas MS

predicted less laughter mimicry via IC. MS and schadenfreude ratings interacted: the more schadenfreude participants perceived the lower was the indirect effect of MS on laughter mimicry. For the disgust scene (figure 3c), IC and MS predicted more laughter mimicry via higher appropriateness. Furthermore, there was an interaction between IC and disgust ratings: the less disgust participants perceived in the laughing other, the higher was the indirect effect of MS on laughter mimicry. In sum, as expected, IC mediated mimicry for both funny and schadenfreude scenes. In line with recent findings that IC is an important predictor of mimicry that is impacted by context, appropriateness and the perceptions of the stimulus which supposedly elicited the laughter predicted IC. For schadenfreude scenes, individual differences were also relevant predictors. The situation was somewhat different for disgust scenes for which appropriateness was a more direct predictor of mimicry. Notably, many participants did not feel close to others who laugh at disgust scenes and hence appropriateness was low overall.

**Table 2.** Mediation analysis: indirect effects. CI, confidence interval; LL, lower limit; UL, upper limit.

effect	estimate	95% CI	
		LL	UL
own laughter during funny scenes			
scene intensity			
via scene relatedness (a1 * b1)	0.0012	0.0001	0.0023
via funniness ratings (a2 * b2)	0.0025	0.0015	0.0034
benign schadenfreude			
via scene relatedness (a3 * b1)	0.009	0.001	0.021
via funniness ratings (a4 * b2)	0.030	0.015	0.049
own laughter during schadenfreude scenes			
scene intensity			
via funniness ratings (a2 * b2)	0.0006	0.0002	0.0010
via repulsiveness ratings (a1 * b1)	−0.0005	−0.0009	−0.0001
deservingness			
via funniness ratings (a3 * b2)	0.0010	0.0005	0.0014
benign schadenfreude			
via funniness ratings (a4 * b1)	0.059	0.039	0.082
via repulsiveness ratings (a5 * b2)	0.007	0.001	0.015
own laughter during disgust scenes			
deservingness			
via funniness ratings (a1 * b)	0.00023	0.00004	0.00049
benign schadenfreude			
via funniness ratings (a2 * b)	0.0072	0.0007	0.0166
sadism			
via funniness ratings (a3 * b3)	0.0038	0.0002	0.0092
laughter mimicry during funny scenes			
appropriateness			
via interpersonal closeness			
for low amusement ratings <sup>a</sup> (a_low * b1)	0.0011	0.0005	0.0017
for mean amusement ratings <sup>a</sup> (a_mean * b1)	0.0013	0.0007	0.0020
for high amusement ratings <sup>a</sup> (a_high * b1)	0.0016	0.0008	0.0024
laughter mimicry during schadenfreude scenes			
appropriateness			
via interpersonal closeness (a1 * b)	0.0016	0.0010	0.0022
benign schadenfreude			
via interpersonal closeness (a2 * b)	0.011	0.007	0.014
malicious schadenfreude			
via interpersonal closeness			
for low schadenfreude ratings <sup>a</sup> (a3_low * b)	−0.016	−0.030	−0.004
for mean schadenfreude ratings <sup>a</sup> (a3_mean * b)	−0.011	−0.022	−0.001
for high schadenfreude ratings <sup>a</sup> (a3_high * b)	−0.005	−0.015	0.004
laughter mimicry during disgust scenes			
interpersonal closeness			
via appropriateness			
for low disgust ratings <sup>a</sup> (a1_low * b)	0.035	0.015	0.055
for mean disgust ratings <sup>a</sup> (a1_mean * b)	0.033	0.014	0.052
for high disgust ratings <sup>a</sup> (a1_high * b)	0.030	0.013	0.048
malicious schadenfreude			
via appropriateness (a2 * b)	0.0049	0.0004	0.0110

<sup>a</sup>Interaction effect, low = −1 s.d., high = +1 s.d.



## 5. Discussion

The present research had the goal to explore the social perception of other's laughter and the consequent mimicry or sharing of that laughter in response to three distinct external events: a 'normatively' funny, a schadenfreude and a disgust scene. First, we were interested in facial expressive responses to these scenes assuming that people 'laugh' more to funny than to schadenfreude and least to disgust scenes. Furthermore, we investigated whether individual differences in trait schadenfreude and sadism as well as SI and deservingness predict funniness and repulsiveness ratings, which, in turn, predict laughter reactions. Second, we assessed (i) whether perceived laughter appropriateness, perceived IC and laughter mimicry are reduced in response to a schadenfreude scene compared to a funny scene and lowest in response to a disgust scene; and (ii) whether individual differences in trait schadenfreude and sadism as well as perceived laughter appropriateness predict perceived IC, which, in turn, predicts laughter mimicry as a form of a social affiliative reaction.

### (a) Own laughter reactions

As predicted, own laughter was less intense in response to schadenfreude scenes than in response to funny scenes and least intense in response to disgust scenes. These effects can both be explained by funniness ratings (funny scenes are funnier than schadenfreude scenes, which are funnier than disgust scenes) and repulsiveness ratings (disgust scenes are more repulsive than schadenfreude scenes, which are more repulsive than funny scenes). Besides the differences between the scenes, however, we were interested in the effects within each scene type. Here, next to funniness and repulsiveness, SI, deservingness and BS played a major role to explain when and why people laugh.

Participants related more to more intense funny scenes, which were also perceived as funnier and elicited stronger laughter. This suggests that, in order to be understood and perceived as funny and then laughed at, benign incongruities have to be relatively intense so that they evoke interest and attract attention. Similarly, schadenfreude scenes that were perceived as more intense were perceived as funnier, which then increased the laughter response. Yet, more intense scenes were also more repulsive, which reduced laughter. This opposing effect of intensity is distinct to schadenfreude, as only those scenes have the potential to be seen as both funnier and more repulsive when they are more intense. Congruent with previous research on schadenfreude [13], for schadenfreude as well as for disgust scenes, deservingness explained why scenes were perceived as funny and evoked laughter. Only if someone deserves to be hurt, it is acceptable to laugh at their misfortune.

Furthermore, BS explained who perceived all three scenes as funny, who felt more related to the funny scene, and less repulsed by the schadenfreude scene, and consequently who showed more laughter reactions. Individuals scoring high on BS seemed to find paradox yet harmless situations funny and situations that are more harmful repulsive, supporting the important distinction between BS and MS [16]. MS by contrast did not explain perceived funniness for any scene. Finally, trait sadism explained why some individuals find disgust scenes funny. In those scenes, a human or an animal experienced something that typically evokes

repulsion. This suggests that laughing at disgust scenes signals more willingness to accept more harm for others and clearly distinguishes this reaction from schadenfreude.

### (b) Perceptions of and reactions to others' laughter reactions

There are various forms of smiles and laughter of which not all are positive and well-meaning [35]. Yet, only expressions that are perceived as positive and appropriate foster affiliation and bonding, which manifests in feelings of IC to the expresser and in facial mimicry reactions [17]. Correspondingly, we found that laughter mimicry was less intense in response to schadenfreude scenes than in response to funny scenes and least intense in response to disgust scenes.

As such, mimicry of others' laughter was dependent on the context. When laughter in response to funny and schadenfreude scenes was perceived as appropriate, it created closeness and elicited mimicry. This finding confirms strong context-dependent top-down effects on mimicry [17]. It also suggests that, in order for laughter to be shared, the laughing individuals must also share a common notion that this behaviour is appropriate. This is more likely for ingroup members who, by definition, share values and beliefs and hence are also likely to share notions of appropriateness [4,6,8]. This was different for disgust, where closeness predicted appropriateness instead. This may be because, here, laughter was generally considered as rather inappropriate and only when the person seemed otherwise likable and hence closer, was the expression more acceptable. Importantly, to the degree that the laughing other was perceived as showing disgust, the appropriate emotion in this context, their laughter was perceived as more appropriate, which suggests that as long as disgust is also signalled, laughing may be more acceptable.

Notably, shared laughter in contexts that included some harm was also influenced by individual difference variables. Whereas mimicry to funny scenes depended only on the perceived degree of amusement and the appropriateness of the laughter, the mimicry of schadenfreude laughter was also linked to BS and MS. Whereas BS increased closeness and laughter, MS decreased both closeness and laughter mimicry, albeit less so when the laughter signalled schadenfreude. Likely, those who enjoy actual suffering to a greater extent seem to react less positively to people who laugh outright at these harmless scenes. Yet, when those scoring high in MS perceived the laughter as indicative of schadenfreude rather than mere amusement, the laughter appeared more legitimate and was mimicked more. MS had the opposite effect for laughter to disgust scenes. Here, it increased both appropriateness and laughter mimicry, in line with the notion that this trait measures a pleasure in harm. Interestingly, sadism did not impact on mimicry. Mimicry is an indicator of empathic responding which is certainly not what characterizes individuals high in sadism. Hence, one could have expected a negative association. However, our sample did generally not score very high on this trait.

In sum, we could show that mimicry of laughter depends both on situational factors, such as the characteristics inherent in a potentially funny event, as well as on differences in the perception of the event. These perceptions then can be partly explained by individual differences such as BS and

MS. Thus, participants did affiliate with others who shared an awkward sense of humour. Yet, bonding with others means not always love, peace and harmony. Affiliation also has a dark side.

### (c) The dark side of affiliation

Affiliating with others who feel pleased at a third person's misfortune or difficult situation is not a particularly uncommon phenomenon. Human social network analyses suggest that a common enemy helps to affiliate with others; it fosters bonding and cohesion [2,6]. Yet, the closer we get to members of our ingroup, the farther away we move from the members of the outgroup [6].

Laughing together may play a major role in this process. Shared laughter signals a shared understanding of the situation and ultimately trust [9]. At the same time, laughing at someone degrades that person's dignity. Mimicry of malicious laughter is very similar to laughing at derogatory jokes or provocative/offensive caricatures, which play down serious matters. Those types of jokes or caricatures are a way to deal with forbidden themes or to dismantle social taboos—but at the same time, they may incite and encourage discrimination [10].

Yet, it is important to note that deservingness plays a major role for *schadenfreude* [13]. Thus, *schadenfreude* laughter might be a punishment of a deviant or morally wrong behaviour; it makes the wrong-doer aware of their socially unacceptable behaviour and consequently may lead to more cautious actions in the future [36]. Sharing *schadenfreude* laughter, in turn, may also serve a social control function: the imitation of such 'sanctioning' laughter may coordinate social behaviour and function to emphasize norms of social justice.

### (d) Strengths and limitations

Our study aimed to investigate the different shades of laughter in response to external events and the social perception and reaction to others' laughter in response to these events. It may not be a big surprise that, on average, *schadenfreude* and disgust scenes elicit less laughter than genuinely funny scenes. Yet, it is interesting that complex cognitive processes, such as evaluating whether an emotional reaction of a counterpart to an external rather ambiguous event is appropriate, have such notable effects on automatic ballistic processes such as mimicry. In fact, mimicry reactions occurred within the first second of the stimulus presentation. As participants did not see the reaction videos simultaneously with the scene videos but a few seconds to even minutes later, they had to remember the scene and quickly assess the appropriateness of the behaviour. Still, the effect was large; laughter in response to disgust scenes was not commonly mimicked, whereas almost every single participant mimicked laughter in response to funny scenes. Thus, our study not only shed light on laughter and its positive and negative consequences for the expresser and the relationship between expresser and observer, but it also gave insights into the top-down processes that impact on facial mimicry [20].

Nevertheless, our study also has some limitations. First, the display of a potentially socially undesirable emotion such as *schadenfreude* may differ depending on the presence or absence of an audience. Sitting at home and watching

others fail may lead to a stronger laughter reaction than being around people who may judge our behaviour (but also to a less intense laughter reaction as here laughter cannot act as a multiplier according to what Provine calls 'contagious laughter' [1]). Yet, as participants were aware of being recorded, even if no actual audience was present, social observation was likely salient enough to make social norms and display rules relevant. Accordingly, even in this not very social experimental situation, we found differences in laughter between the *schadenfreude* and the other two scenes. Second, due to technical reasons, our stimuli were presented without sound, which may have weakened the effect both scenes and reaction videos had on participants' evaluations and reactions. Still, we found clear differences between scenes and also the reaction videos had the intended effects. Furthermore, we used a facial behaviour analysis toolkit to measure participants' facial expressions. In contrast with EMG, this method does not detect subtle muscle movements or covert facial reactions. Yet, as we were interested in laughter and laughter mimicry, the detection of subtle invisible reactions was not the focus of our study.

Finally, our measure of facial activity did not allow us to distinguish between laughter and smiling. In fact, visual inspection of the participants' videos suggests that participants predominately laughed in response to the scenes, probably because feelings of amusement and *schadenfreude* elicit more laughter than smiles [37]. By contrast, participants more typically smiled than laughed in response to laughter reactions. Yet, both behaviours have the same phylogenetic root. Due to their morphological commonalities, it is plausible to assume that they have evolved from the ancestral open-mouth play face [38,39]. Importantly, these open-mouth displays have also been observed in primates after the observation of unexpected behaviours, that is, behaviours that are incongruent to expectations, which further underlines their functional similarity to human laughter and smiles [9,38,39]. Hence, in many contexts, laughter and smiling may be interchangeable behaviours with the only difference that smiling can be considered a weak version of laughter [40] during which the same facial muscles are activated albeit less strongly [37]. Consequently, both expressions may have had the same inherent meaning and also similar implications in the context of our study. Thus, we suggest that—especially as spontaneous facial mimicry reactions are typically more subtle and not of the same intensity as prototypical (posed) emotion expressions [41]—smiling in response to laughter should have been an appropriate proxy for shared laughter (i.e. laughter mimicry) that signals affiliation and fosters bonding [20].

## 6. Conclusion

Laughter is an ambiguous phenomenon that has opposing effects—even at the same time. Laughter mimicry in response to an event that may evoke *schadenfreude* means, on the one hand, bonding and affiliation with an expresser who laughs about others' deserved misfortune. On the other hand, it signals rejection and social exclusion intentions towards the target of the laughter. Thus, our findings underline the ambiguous nature of laughter, and they give further support for the notion that facial mimicry has a social signal and hence social control function [20].

**Ethics.** The study was conducted in accordance with the guidelines of the Declaration of Helsinki and approved by the Department's Ethics committee (application no.: 2021-30).

**Data accessibility.** The data is available from OSF: <https://osf.io/sge8n/>.

**Authors' contributions.** H.M.: conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, supervision, visualization, writing—original draft and writing—review and editing; T.K.: conceptualization, investigation, methodology, software, supervision and writing—review and editing; A.H.: investigation, methodology, software and writing—review and editing; A.S.: investigation, methodology, software and writing—review and editing; U.H.: conceptualization, funding acquisition, methodology, project administration, resources, software, supervision, validation, writing—original draft and writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

**Conflict of interest declaration.** We declare we have no competing interests.

**Funding.** We received no funding for this study.

**Acknowledgements.** We would like to thank Felicia Tölle for her help during the stimulus selection process and during the data collection for the pretest.

## Endnotes

<sup>1</sup>Data from the latter will not be discussed in the present manuscript. We have added short explanations for each scale to the electronic supplementary materials part C.

<sup>2</sup>Adding sex as covariate to the main analyses did not change the size of the effects of scene on our relevant outcome measures, even though it explained additional variance in the one or the other outcome measure (see electronic supplementary materials part E).

<sup>3</sup>To reduce the complexity of the model, we aggregated scores on trial level.

<sup>4</sup>We have added comparisons of model performance indices to justify the selection of our six mediation models to the electronic supplementary materials (part F).

## References

- Provine RR. 2001 *Laughter: a scientific investigation*. Baltimore, MD: Penguin.
- Panksepp J, Burgdorf J. 2003 'Laughing' rats and the evolutionary antecedents of human joy? *Physiol. Behav.* **79**, 533–547. (doi:10.1016/S0031-9384(03)00159-8)
- Hofmann J, Ruch W. 2015 Gibt es ein Lachen der Schadenfreude? *Z. Semiot.* **37**, 55–79. (doi:10.14464/SEMOTIK.V37I1-2.337)
- Smith RH. 2013 *The joy of pain: schadenfreude and the dark side of human nature*. Oxford, UK: Oxford University Press.
- Hareli S, Weiner B. 2002 Dislike and envy as antecedents of pleasure at another's misfortune. *Motiv. Emot.* **26**, 257–277. (doi:10.1023/A:1022818803399)
- Knight NK. 2010 Wrinkling complexity: concept of identity and affiliation in humour. In *New discourse on language functional perspectives on multimodality, identity, and affiliation* (eds M Bednarek, JR Martin), pp. 35–58. London, UK: Bloomsbury Publishing.
- Gervais M, Wilson DS. 2005 The evolution and functions of laughter and humor: a synthetic approach. *Q. Rev. Biol.* **80**, 395–430. (doi:10.1086/498281)
- Flamson TJ, Bryant GA. 2013 Signals of humor. In *Developments in linguistic humour theory* (ed. M Dynel), pp. 49–74. Amsterdam, The Netherlands: John Benjamins. (doi:10.1075/thr.1.04fla)
- Martin RA, Ford T. 2018 *The psychology of humor: an integrative approach*. New York, NY: Academic Press.
- McGraw AP, Warner J. 2014 *The humor code: a global search for what makes things funny*. New York, NY: Simon and Schuster.
- Ben-Ze'ev A. 2014 The personal comparative concern in schadenfreude. In *Schadenfreude: understanding pleasure at the misfortune of others* (eds WW van Dijk, JW Ouwerkerk), pp. 77–90. Cambridge, UK: Cambridge University Press. (doi:10.1007/9781139084246.007)
- Van De Ven N. 2014 Malicious envy and schadenfreude. In *Schadenfreude: understanding pleasure at the misfortune of others* (eds WW van Dijk, JW Ouwerkerk), pp. 110–117. Cambridge, UK: Cambridge University Press.
- Feather NT. 2014 Deservingness and schadenfreude. In *Schadenfreude: understanding pleasure at the misfortune of others* (eds WW van Dijk, JW Ouwerkerk), pp. 29–57. Cambridge, UK: Cambridge University Press.
- Oppliger PA, Zillmann D. 1997 Disgust in humor: its appeal to adolescents. *Humor* **10**, 421–437. (doi:10.1515/humr.1997.10.4.421)
- McDougall W. 1922 A new theory of laughter. *Psyche (Stuttg.)* **2**, 292–303.
- Crysel LC, Webster GD. 2018 Schadenfreude and the spread of political misfortune. *PLoS ONE* **13**, 1–27. (doi:10.1371/journal.pone.0201754)
- Kastendieck T, Mauersberger H, Blaison C, Ghalib J, Hess U. 2021 Laughing at funerals and frowning at weddings: top-down influences of context-driven social judgments on emotional mimicry. *Acta Psychol.* **212**, 103195. (doi:10.1016/j.actpsy.2020.103195)
- Scarantino A, Hareli S, Hess U. In press. Emotional expressions as appeals to recipients. *Emotion*. (doi:10.1037/emo0001023)
- Hess U, Fischer A. 2013 Emotional mimicry as social regulation. *Personal. Soc. Psychol. Rev.* **17**, 142–157. (doi:10.1177/1088868312472607)
- Hess U. 2021 Who to whom and why: the social nature of emotional mimicry. *Psychophysiology* **58**, e13675. (doi:10.1111/psyp.13675)
- Niedenthal PM, Barsalou LW, Winkielman P, Krauth-Gruber S, Ric F. 2005 Embodiment in attitudes, social perception, and emotion. *Personal. Soc. Psychol. Rev.* **9**, 184–211. (doi:10.1207/s15327957pspr0903\_1)
- Wood A, Rychlowska M, Korb S, Niedenthal P. 2016 Fashioning the face: sensorimotor simulation contributes to facial expression recognition. *Trends Cogn. Sci.* **20**, 227–240. (doi:10.1016/j.tics.2015.12.010)
- Goldman AI, Sripada CS. 2005 Simulationist models of face-based emotion recognition. *Cognition* **94**, 193–213. (doi:10.1016/j.cognition.2004.01.005)
- Schönbrodt FD, Perugini M. 2013 At what sample size do correlations stabilize? *J. Res. Pers.* **47**, 609–612. (doi:10.1016/j.jrp.2013.05.009)
- Jansen MP, Truong KP, Nazareth DS, Heylen DKJ. 2020 Introducing MULAI: a multimodal database of laughter during dyadic interactions. In *LREC 2020 - 12th Int. Conf. Language Resources and Evaluation, Conf. Proc., Marseille, France*, pp. 4333–4342.
- Aron A, Aron EN, Smollan D. 1992 Inclusion of other in the self scale and the structure of interpersonal closeness. *J. Pers. Soc. Psychol.* **63**, 596–612. (doi:10.1037/0022-3514.63.4.596)
- Neumann CS, Jones DN, Paulhus DL. 2021 Examining the Short Dark Tetrad (SD4) across models, correlates, and gender. *Assessment* **29**, 1073191120986624. (doi:10.1177/1073191120986624)
- Spreng RN, McKinnon MC, Mar RA, Levine B. 2009 The Toronto empathy questionnaire: scale development and initial validation of a factor-analytic solution to multiple empathy measures. *J. Pers. Assess.* **91**, 62–71. (doi:10.1080/00223890802484381)
- Baltrusaitis T, Zadeh A, Lim YC, Morency LP. 2018 OpenFace 2.0: facial behavior analysis toolkit. In *Proc. 13th IEEE Int. Conf. Automatic Face and Gesture Recognition (FG 2018)*, pp. 59–66.
- Ekman P, Friesen WV. 1978 *Facial action coding system (FACS): a technique for the measurement of facial action*. Palo Alto, CA: Consulting Psychologists Press.
- Drimalla H, Scheffer T, Landwehr N, Baskow I, Roepke S, Behnia B, Dziobek I. 2020 Towards the automatic detection of social biomarkers in autism spectrum disorder: introducing the simulated

- interaction task (SIT). *npj Digit. Med.* **3**, 1–10. (doi:10.1038/s41746-020-0227-5)
32. Hess U, Arslan R, Mauersberger H, Blaison C, Dufner M, Denissen JJA, Ziegler M. 2017 Reliability of surface facial electromyography. *Psychophysiology* **54**, 12–23. (doi:10.1111/psyp.12676)
  33. MacKinnon DP. 2012 *Introduction to statistical mediation analysis*. New York, NY: Routledge.
  34. Tofighi D, MacKinnon DP. 2011 RMediation: an R package for mediation analysis confidence intervals. *Behav. Res. Methods* **43**, 692–700. (doi:10.3758/s13428-011-0076-x)
  35. Niedenthal PM, Mermillod M, Maringer M, Hess U. 2010 The simulation of smiles (SIMS) model: embodied simulation and the meaning of facial expression. *Behav. Brain Sci.* **33**, 417–433. (doi:10.1017/S0140525X10000865)
  36. Elison J. 2019 Interpreting instances of shame from an evolutionary perspective: the pain analogy. In *The bright side of shame* (eds C-H Mayer, E Vanderheiden), pp. 395–411. Cham, Switzerland: Springer International Publishing.
  37. Hofmann J, Platt T, Ruch W. 2017 Laughter and smiling in 16 positive emotions. *IEEE Trans. Affect. Comput.* **8**, 495–507. (doi:10.1109/TAFFC.2017.2737000)
  38. Davila-Ross M, Jesus G, Osborne J, Bard KA. 2015 Chimpanzees (*Pan troglodytes*) produce the same types of 'laugh faces' when they emit laughter and when they are silent. *PLoS ONE* **10**, 1–11. (doi:10.1371/journal.pone.0127337)
  39. Davila-Ross M, Dezechache G. 2021 The complexity and phylogenetic continuity of laughter and smiles in hominids. *Front. Psychol.* **12**, 1–10. (doi:10.3389/fpsyg.2021.648497)
  40. Frijda NH. 1986 *The emotions*. Cambridge, UK: Cambridge University Press.
  41. Höfling TTA, Alpers GW, Gerdes ABM, Föhl U. 2021 Automatic facial coding versus electromyography of mimicked, passive, and inhibited facial response to emotional faces. *Cogn. Emot.* **35**, 874–889. (doi:10.1080/02699931.2021.1902786)