Emotional content—not source credibility—determines the cognitive effort invested in processing social misinformation

Julia Baum^{1,2}, Romy Frömer³, and Rasha Abdel Rahman^{1,2}

¹Humboldt-Universität zu Berlin, Faculty of Philosophy, Berlin School of Mind and Brain

²Humboldt-Universität zu Berlin, Faculty of Life Sciences, Department of Psychology

³Cognitive, Linguistic, and Psychological Sciences, Carney Institute for Brain Science, Brown University

Abstract

Emotionality likely is a key factor affecting our susceptibility to misinformation. However, the mechanisms underlying this observation are not well understood. Specifically, when people derive social information from person-related news, they rely predominantly on the emotional contents, apparently unperturbed by the credibility of the source. To help explain this bias, we here contrast two hypotheses of information processing reflected in changes in pupil size during news-based judgments: Emotion and cognitive effort. Thirty participants were first exposed to websites of well-known trusted or distrusted news media sources exhibiting headlines about unfamiliar persons, followed by social judgments. As expected, emotional relative to neutral headline contents lead to faster and more strongly valenced judgments. In line with the cognitive effort hypothesis, credibility modulated pupil size with larger pupils for headlines from distrusted sources, however only in response to neutral news. Source credibility did not modulate pupil size in response to emotional news. Instead, pupil size was smaller for emotional compared to neutral news for both trusted and distrusted sources. This pattern of findings suggests that emotional contents yield fluent social judgments that are made with relatively little mental effort—even if based on untrustworthy news. Cognitive resources to evaluate the credibility of news may primarily be allocated when emotional contents providing (false) fluency are not available. This insight into the biases underlying the processing of misinformation may be used as a protection against biased opinions and judgments.

Keywords

pupillometry, fluency, cognitive effort, misinformation, emotion, person knowledge

Corresponding Author:

Julia Baum, julia.baum@hu-berlin.de

Humboldt-Universität zu Berlin, Institut für Psychologie, Unter den Linden 6, 10099 Berlin

While trustworthy person-related information can be highly valuable to navigate the social world, social misinformation, that is, “information that is false, inaccurate or misleading” (Treen et al., 2020, p.2), can bias opinions, defame others, and may even lead to wrongful convictions. The credibility people attribute to media sources can help to assess the veracity of news (Lorenz-Spreen et al., 2020; Metzger & Flanagin, 2013; Pennycook & Rand, 2019). Despite this ability to identify potential misinformation, people do not necessarily use their knowledge of source credibility when they form opinions and derive judgments about other persons from social information in news. While being remarkably insensitive to the credibility of news sources, participants’ social judgments and their neural correlates are strongly influenced by the emotional content of news (Baum & Abdel Rahman, 2020; 2021; Baum et al., 2018). What basic cognitive mechanisms can explain why and how emotional content is instrumental in people’s susceptibility to social information they don’t trust?

Previous research on the topic of misinformation and “fake news” has investigated in large-scale observational and behavioural studies, for instance, how information cascades through social networks, how well crowds and people can discern true from false information, what they share, and what interventions or algorithms could reduce the spread of misinformation and correct it (e.g., Ecker et al., 2022; Kozyreva et al., 2020; Lorenz-Spreen et al., 2020; Pennycook & Rand, 2021; Vosoughi et al., 2018). Yet little is known about the consequences of (mis)information on the micro-scale of the individual neuro-cognitive system, and our work contributes with this complementary perspective (Baum & Abdel Rahman, 2020; 2021; Baum et al., 2018).

Here, we analyse pupil dilation as a measure that has been related to both, emotional processing and cognitive effort. Emotion vs. cognitive effort as driving forces for effects of social misinformation make differential predictions that can be tested by analysing pupil size during social judgments. By tracking changes in pupil size in our controlled experimental setting, we investigate how the credibility and the content of news is processed when people judge the persons featured in the news (Fig.1). Forming social opinions from person-related information is a natural tendency (Abdel Rahman, 2011; Bliss-Moreau et al., 2008; Ferrari et al., 2020), and even untrustworthy information can bias opinions (Baum et al., 2018; Baum & Abdel Rahman, 2020; 2021). We investigate these social evaluations by first exposing participants to person-related news headlines with negative, positive, or relatively neutral contents from trusted or distrusted sources (Phase 1). Subsequently, we investigate the consequences of news exposure on pupil size during social judgments of the persons presented in isolation (Phase 2).

Pupil size can shed light on cognitive-emotional processes underlying social judgments as small-scale, task-evoked pupil changes can reflect input from cortical brain regions, such as the cingulate and prefrontal cortex, and the amygdala (Beatty & Lucero-Wagoner, 2000; Granholm & Steinhauer, 2004; for a systematic review of cognitive and emotional influences see Peinkhofer et al., 2019). The locus-coeruleus norepinephrine arousal system has been proposed as a neural mechanism underlying these cortical innervations (Aston-Jones & Cohen, 2005). In response to a given task, phasic changes in pupil size reflect processing of salient information evoked by the task-relevant stimuli, also described as increase in adaptive gain and

narrowing of attention (Aston-Jones & Cohen, 2005; Gilzenrat et al., 2010; van der Meer et al., 2010).

Pupil size is a suitable measure to discriminate between competing hypotheses regarding emotion and cognitive effort. On the one hand, pupil size can scale with affective arousal of processing emotions such as fear (Kuniecki et al., 2018; Liddell et al., 2007; Marther et al., 2016). For instance, compared to emotionally neutral stimuli, pupils enlarge in response to arousing affective signals like hearing someone cry in sadness, seeing angry expressions of faces or bodies, pleasant or unpleasant scenes, or emotionally moving artwork (e.g., Bradley et al., 2008; Kret et al., 2013; Kuchinke et al., 2009; Oliva & Anikin, 2018). On the other hand, pupil size can scale with cognitive effort, as in how much processing load is involved (Beatty, 1982; Beatty & Lucero-Wagoner, 2000; Beatty & Kahneman, 1966; Kahneman et al., 1969; Just et al. 2003); so that the more resources allocated, the larger the pupil and vice versa (e.g., Nuthmann & van der Meer, 2005; Raisig et al., 2007; Peinkhofer et al., 2019; Verney et al., 2004; van der Meer et al., 2010). For example, pupil size has been demonstrated to be sensitive to the cognitive effort involved in reading (Shechter & Share, 2021). Increases in effort can be related to uncertainty and attempts to resolve it, for example by sampling more information (Aston-Jones & Cohen, 2005; Nassar et al., 2012; Yu & Dayan, 2005). A large body of research has shown that the pupil enlarges in response to increased cognitive effort in many domains, for instance in language processing, emotion and reappraisal, memory recall, decision making, cognitive control, and mental arithmetic (e.g., Bayer et al., 2011; Beatty & Lucero-Wagoner, 2000; Beatty, 1982; Engelhardt et al., 2010; Gilzenrat et al., 2010; Just et al., 2003; Kahneman et al., 1969; Papeš & Goldinger, 2012; Peinkhofer et al., 2019; Prehn et al., 2011; Shechter & Share, 2021; Sirois & Brisson, 2014; Steinhauer et al., 2004; van der Meer et al., 2003, 2010; van der Wel & van Steenbergen, 2018; Yih et al., 2019).

To conceptualize how the emotional contents and the credibility of news may be processed, we refer to dual-process and iterative updating theories, as well as appraisal theories of emotion that generally differentiate between fast, relatively automatic processes related to emotional arousal and slow, more controlled processes related to reflective evaluation (Cunningham & Zelazo, 2007; Gawronski & Bodenhausen, 2006; FeldmanHall & Shenhav, 2019; Kahneman, 2003; Lieberman, 2007; Strack & Deutsch, 2004; Yonelinas, 2002; and Ellsworth and Scherer, 2003; Scherer, 2001). Based on these theories, we predict that more automatic processes would be mainly influenced by the emotional content whereas critically, later, more controlled processes would take the credibility of the source into account, resulting in balanced social judgments.

We tested two alternative predictions for pupil size during social judgments (Fig.2). According to the emotion hypothesis, larger pupils reflect emotional arousal. Accordingly, pupil size should be enlarged for faces associated with emotional contents relative to neutral headline contents. Based on previous electrophysiological evidence of emotional arousal-related processing (Baum & Abdel Rahman, 2020; 2021, using the same study design with different participants), we expected that such emotion effects should be found regardless of source credibility.

Alternatively, according to the effort hypothesis, larger pupils reflect more cognitive effort involvement, primarily driven by uncertainty and the unavailability of strong evidence for the judgment. Thus, if the credibility of the source is processed, more effort reflected in

larger pupils should be involved when headlines came from distrusted sources. Emotional content should—due to its supposed strong evidence—be associated with less effort and smaller pupils, whereas neutral content should lack that kind of evidence and require more effort.

Figure 1. Study phases, key experimental manipulations, and results of manipulation checks. **Phase 1:** **A.** Participants rated the likability of unfamiliar persons before and after news exposure. **B.** During news exposure, participants viewed websites of trusted and distrusted sources that contained the news media source logo, the face, and the person-related headline with all other details blurred. To

control for influences of the features of individual faces, the assignment of face, source, and headline was counterbalanced across participants. Authentic websites of existing and widely distributed German news media were selected based on their pre-rated high or poor credibility due to their differences in fact checking, in providing or lacking context information, and in using appropriate or misleading headlines (e.g., Tagesschau or Bild). Comparable English-speaking media are for example The Guardian, NBC News, Fox News, or The Sun. As in previous studies and like in everyday life, participants were provided with clearly visible source information via the logo and characteristic layout but were not explicitly instructed to contemplate on the credibility of news. In this design, participants look at the source logo during news exposure (shown by eye-tracking in Baum & Abdel Rahman, 2020). **C.** Headline content successfully influenced person likability. **Phase 2:** In the social judgment task, the faces were presented in isolation and the participant's pupil size was acquired while they judged the depicted person based on all the information of Phase 1. **Phase 3:** Media source checks (**D.**) confirmed that sources were differentiated in trustworthiness (**E.**) and likability (**F.**). **C., E., F.** Raincloud plots (Allen et al., 2019) show means and 95% confidence intervals calculated with the summarySEwithin function (Morey, 2008) on single trial data, and points, and distributions for data aggregated by subject

Figure 2. Two alternative predictions underlying pupil size effects. Task-evoked changes in pupil size can index differential cognitive or emotional processes underlying the processing of information when people derive judgments from news. The emotion hypothesis reflects enlarged pupils associated with emotional processing. The effort hypothesis reflects enlarged pupils associated with cognitive effort involvement related to uncertainty and the lack of strong evidence.

Method

Sample Size

The following power analysis of linear mixed models by simulation was pre-registered on OSF². The sample size was planned according to the counterbalancing of conditions and based on expected estimates of pupil size effects. A multiple of 6 participants is required to counterbalance the assignment of information to faces in our within-subject design. To estimate the expected power to find fixed main effects of negative and positive headline content, and interaction effects with source credibility in the linear mixed model analysis, we ran simulations (1000 each) using the SIMR package in R for a sample of 30 participants (Green & MacLeod, 2016).

Literature suggests that pupillary response effects towards faces are about 0.05 mm. Pupil size effects in similar tasks of faces associated with information (e.g., motivational salience, reappraisal) resulted in about 0.05 mm changes (e.g., Hammerschmidt et al., 2018, Yih et al., 2018). Additionally, ERP results (Baum et al., 2018; Baum & Abdel Rahman, 2020) have shown numerically slightly weaker emotion effects of positive than of negative information compared to neutral.

Pupil size changes towards faces (grand mean intercept of 0.1 mm) may result in different outcomes according to our hypotheses. Relatively strong main effects of headline content valence may be accompanied by relatively small interaction effects with source credibility and no main effect of source credibility (power analysis 1, see Table 1), or relatively small main effects of headline content may be accompanied by relatively strong source credibility effects and modulations (power analysis 2, see Table 1).

Table 1

Power analyses for pupil size effects. Power analysis 1 refers to the emotion hypothesis, power analysis 2 refers to the effort hypothesis.

Coefficient	Power analysis 1 Estimate in mm and predicted power with 95% confidence interval	Power analysis 2 Estimate in mm and predicted power with 95% confidence interval
Source Credibility (Trusted vs. Distrusted)	.001 (not predicted)	.008 100% CI [99.63, 100.0]
Negative Headline Content (Neg vs. Neu)	.05 100 % [99.63, 100.0]	.005 94.30 % CI [92.68, 95.65]
Source Credibility * Negative Headline Content	.009 87.70 % [85.50, 89.67]	.01 93.70% CI [92.01, 95.13]
Positive Headline Content (Pos vs. Neu)	.04 100 % [99.63, 100.0]	.004 81.30 % [78.74, 83.67]
Source Credibility * Positive Headline Content	.008 81.10 % [78.53, 83.48]	.008 79.80 % CI [77.18, 82.25]

Participants

The analyzed data set consisted of thirty participants, as preregistered (mean age = 25.77 ($SD = 5.46$), 22 females, 8 males, 29 right-handed). Participants were asked to not have consumed recreational drugs within 48hrs before the experiment and to not wear eye make-

² Is available to the reviewers and upon publication.

up. Twelve participants were excluded and replaced with new participants (reasons: four because of technical problems with the eye tracker (e.g., interference with glasses' frames), four were presented with wrong stimulus material, two did not acquire person-related information, two rated the trustworthiness contrary to the pre-ratings of source credibility). Participants were compensated with course credit or money. They were (de)briefed about the procedures and signed informed consent. The study was approved by the local ethics committee.

Materials

For the news exposure in Phase 1, websites of news media were manipulated to combine source logo, headline, and face with all other details blurred maintaining the original layouts (for examples see Fig. 1B; all materials were equivalent to Baum & Abdel Rahman, 2020; 2021). The assignment of faces was equally counterbalanced to headlines and sources between participants. Thus, any effects of headlines and sources are free of confounds due to the individual features or lighting conditions of faces.

Sources were well-known German news media. Four trusted and four distrusted sources were selected based on pre-ratings of credibility and familiarity ('Bild', 'Bunte', 'B.Z. Berlin', 'Frankfurter Allgemeine', 'Gala', 'Sueddeutsche', 'Tagesschau', 'Zeit Online'; see SI-page 10 for pre-ratings, the Supplemental Information is attached at the end of this manuscript). For the news media source checks in Phase 3, the source logos were presented (Fig. 1D).

Headlines were either of neutral, positive, or negative valence. The headlines were pre-rated by different participants on valence and arousal, and arousal of positive and negative content was matched (e.g., neutral: *Startup scene: He invests in smart household appliances*; positive: *Scientific breakthrough: This researcher restores sight for blind people*; negative: *Berlin: This casino owner forced teenager to smuggle cocaine*; for valence and arousal pre-ratings and full list of headlines please see SI-page 10).

Twenty-four unfamiliar faces with neutral facial expressions were taken from different databases (e.g., Ebner et al., 2010; Langer et al., 2010). Eight well-known persons were included as fillers (2 negative, 2 positive, 4 neutral). For news exposure, the faces were shown with backgrounds (e.g., wall, room) and placed on the website. In Phase 2 and for person likability ratings, faces were presented in isolation as colored photographs on a grey background (2.7×3.5cm, viewing distance 70cm; see Fig.1 Phase 2).

Procedure

We used a well-established within-subject design also employed in electrophysiological research that counterbalances the key manipulations and carefully controls the stimuli presented when dependent variables are measured (e.g. Abdel Rahman, 2011; Baum et al., 2018; Suess et al., 2015). The paradigm enables these controlled measurements by manipulating variables of interest (news in form of websites with the face, headline, and source) exclusively during news exposure and presenting faces associated with the manipulated knowledge in isolation during psychophysiological recordings.

The procedure consisted of three Phases (Fig.1; mainly equivalent to Baum & Abdel Rahman, 2020). In Phase 1, a manipulation check tested the likability of all faces before (Fig. 1, Phase 1), and 15-minutes after the news exposure (pre-exposure and post-exposure person likability ratings on 5-point scales from likable to unlikable). We included this likability rating as it can be done based on a spontaneous feeling of liking without further information about a person and thereby provides a pre-post measure as manipulation check. For the news exposure, participants were told that they received information in form of media reports about the persons and that unrelated details were blurred. Websites were presented in blocks of 8 (pseudo-randomized to include all conditions and two fillers) and repeated 5 times in total with each presentation lasting 6s (for the first second only the source logo was unblurred, for the remaining 5s also the face and headline were unblurred). Baum & Abdel Rahman (2020) confirmed in an eye-tracking manipulation check during news exposure that participants acknowledge the media source logo when they view news. To keep participants engaged, they occasionally answered short yes-or-no questions about the persons, e.g. *Is the behavior of this person common?* (asked in about 22% of the trials of Phase 1).

In Phase 2 participants performed the social judgment task, where the persons were presented in isolation and during which participants' pupil size was recorded (Fig. 1, Phase 2). Participants made explicit valenced judgments on a 5-point scale referring to the person and their social characteristics based on the information acquired in Phase 1. The social judgment task was repeated 10 times block-wise separated by breaks and participants were told that this is necessary for eye measurements. In each trial, a face was presented for 3.5 seconds, followed by a blank screen for 1s to allow for excessive blinking. In the end of Phase 2 a separate task followed, in which participants indicated how confident they were in their social judgments, and which is reported in a different paper (Baum et al., 2022).

Phase 3 entailed manipulation checks of the sources (Fig. 1, Phase 3). Participants were presented with the logos of the media sources and answered if they knew each source, and rated how trustworthy they perceived each source, and how likable they found each source.

The direction of scales was counterbalanced between participants, and consistent within each participant for all tasks, i.e. there were two versions, in version one the 5 buttons ranged from positive (left) to negative (right), and in version two from negative (left) to positive (right).

We included additional tests at the end of the experiment. We checked if the blurred layouts of websites in themselves provide cues of the media source. Participants assigned screenshots of websites where the logo had been removed to one of two sources (trusted or distrusted). 83% of the layouts were correctly identified ($M=.83$, 95%-CI [.80,-], $t(29)=46.54$, $p<.001$, $d=8.5$). For an exploratory memory test of the sources, we showed participants each face along with two source logos and participants chose the source where the person had appeared in (forced choice). If the person had appeared in a trusted source, the distractor was a distrusted source and vice versa. Participants were better than chance in assigning the correct source (trusted or distrusted) across faces ($M=.60$, 95%-CI [.56,65], $t(29)=4.49$, $p<.001$, $d=4.76$). Classifications were marginally more often correct for trusted sources than for distrusted ($b=1.66$, 95%-CI [1.00, 2.75], $t=1.96$, $p=.049$). Importantly, all other coefficients (headline content, interactions of headline content and source credibility) had no influence on correct classifications ($ts < |1.3|$, $ps > .20$; please see SI-Tables S8, S9). To check that participants remembered the broad information of the headlines (inclusion criterion), they received a list

with all faces and wrote down contents of each headline. Participants reproduced correct details for 95% (95%-CI [0.92, 0.97]) of the faces, with no difference between conditions ($p > .28$).

Pupil diameter recording and preprocessing

Pupil size was registered during the social judgment task (SMI Red, SensoMotoric Instruments, Inc., Boston, MA). The system was calibrated before the task and participants' chins rested on a head rest during the task and illuminance in the lab cabin was at about 50lx. Pupil size was recorded of both eyes with a sampling rate of 120Hz and face onset triggers were sent to the continuous signal.

Offline, eye tracking data was converted into Matlab files (Dimigen et al., 2011) and segment information was extracted (1s before stimulus onset up until 3.5s after defined one segment). Invalid samples were rejected including the edge samples 110ms before and after the artifacts. To detect artifacts, we used the Matlab script to detect invalid samples by Kret & Sjak-Shie, 2018 that identifies three types of frequently occurring artifacts: Dilation speed outliers and edge artifacts, trend-line deviation outliers, temporally isolated samples, and outliers outside the allowed range of 1.5mm to 9mm diameter (please see SI for more details on settings). The mean pupil size of both eyes' remaining valid samples was segmented into epochs of 3.6s, starting 100ms prior to stimulus onset. Gaps smaller than 250ms were interpolated (using *pracma* in R) and epochs with gaps bigger than 250ms and changes in pupil size bigger than 1.2mm were rejected. An average of 29 trials remained per participant per condition (no difference between conditions, $F_s < 2.3$, $p_s > .14$) and on average 73% of trials were kept per condition overall (neutral-trusted 873, neutral-distrusted 865, negative-trusted 898, negative-distrusted 882, positive-trusted 890, positive-distrusted 863). The mean dilation during a 100ms pre stimulus baseline was subtracted for each epoch (Mathôt et al., 2018). The baseline pupil diameter did not differ between conditions ($F_s < .7$, $p_s > .5$).

We analyzed pupil dilation data on single-trial level in 200ms averaged time-bins from 400ms to 3000ms after stimulus onset. For each time-bin we fitted a mixed-effects model and applied a false discovery rate correction to p-values (Benjamin & Hochberg, 1995).

Data analysis

We used linear mixed models (LMMs) on single-trial data of behavioral measures and task-evoked pupil dilation (cf. Frömer et al., 2018; Bates et al., 2015b: *lme4* v.1.1-17 in R). For each dependent variable, the model was specified with fixed effects for the experimental factors *headline content* (negative, positive, neutral; with neutral as the reference level) and *source credibility* (trusted, distrusted) and their interaction. Both factors were modeled as repeated contrasts that compare the means of factor levels to the respective reference level (Schad et al., 2020). We fitted models with a maximal crossed random-effects structure correcting for by-subjects and by-face-stimuli random intercepts and slopes. If necessary, random-slopes correlation parameters were set to zero and slopes explaining zero variance were omitted to achieve convergence and avoid overparameterization (Bates et al., 2015a; final random structures are reported in the results Tables). To test the significance of fixed effects coefficients (p-value $< .05$) we used the Satterthwaite approximation as implemented in the *summary* function of *lmerTest* (v.3.0-1, Kuznetsova et al., 2017). To follow-up interactions,

we re-ran the same LMM with nested fixed effects (cf. Schad et al., 2020). Data and code can be accessed online³.

Manipulation checks

Pre- and post- news exposure person likability ratings (Phase 1)

We validated that person perceptions were impacted by news exposure (Fig.1 Phase 1). Before news exposure person likability ratings were on average neutral ($ts < |1.5|$, $ps > .15$, please see SI-Table S3, S4). After news exposure, persons were rated as likable when they had been associated with positive headlines ($b = .61$, 95%-CI [.44, .79], $t = 6.91$, $p < .001$) and they were rated as unlikable when they had been associated with negative headlines ($b = -1.56$, 95%-CI [-1.80, -1.31], $t = -12.43$, $p < .001$). Likability ratings were not modulated by source credibility ($ts < |1.5|$, $ps > .15$, please see SI-Tables S4, S5).

News media source checks (Phase 3)

We verified that all participants were familiar with all media sources and identified their trustworthiness in line with our manipulation, see Fig.1 Phase 3. Distrusted sources were rated as untrustworthy and less likable, and trusted sources were rated as trustworthy and likable (source credibility effect in trust ratings: $b = 2.63$, 95%-CI [2.17, 3.10], $t = 11.15$, $p < .001$, in likability ratings: $b = 2.31$, 95%-CI [1.71, 2.91], $t = 7.58$, $p < .001$; see SI-Tables S5, S6).

Results

Social judgments and their latencies

Social judgments relied on headline content but were unaffected by source credibility, replicating the finding by Baum & Abdel Rahman (2020; 2021), see Fig. 3 and Table 2 for LMM statistics, SI-Table S1 for descriptive means. Persons associated with negative relative to neutral headlines were judged as more negative and persons associated with positive headlines were judged more positive relative to neutral. Source credibility had no influence on social judgments and there was no interaction between negative or positive headline content effects and source credibility. Judgment latencies showed the same pattern, namely that both negative and positive headlines led to faster judgments compared to neutral headlines, but latencies were not affected by source credibility.

³ Data and code is available to the reviewers and upon publication.

Figure 3. Social judgments are sensitive to emotional content, but not source credibility. **A.** In Phase 2, participants judged persons based on the information from Phase 1 on a 5-point scale from positive to negative while their pupil size were recorded. Faces were presented for 3.5s. **B.** Social judgments relied on the emotional headline content regardless of source credibility. **C.** Judgments were made faster when faces had been associated with emotional content compared to neutral content. Shown are raincloud plots (Allen et al., 2019) with means and 95% confidence intervals calculated with the *summarySEwithin* function (Morey, 2008) on single trial data, and points, and distributions for data aggregated by subject.

Table 2

LMM summary statistics show effects of source credibility, negative and positive headline content and their interactions on behavioral dependent variables in the social judgment task. Effects on social judgment decisions and latencies were estimated in separate LMMs and fixed effects were coded as repeated contrasts.

<i>Coefficient</i>	Social Judgment Decisions				Social Judgment Latencies [-1000/latency(ms)]			
	<i>b (95%-CI)</i>	<i>SE</i>	<i>t</i>	<i>p</i>	<i>b (95%-CI)</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Intercept (Grand Mean)	-0.06 (-0.19 – 0.06)	0.06	-1.00	0.323	-1.18 (-1.25 – -1.11)	0.04	-32.10	<0.001
Source Credibility (Trusted vs. Distrusted)	0.01 (-0.11 – 0.12)	0.06	0.09	0.927	0.00 (-0.02 – 0.02)	0.01	0.06	0.953
Negative Headline Content (Neg vs. Neu)	-1.96 (-2.17 – -1.75)	0.11	-18.32	<0.001	-0.18 (-0.23 – -0.13)	0.03	-6.61	<0.001
Source Credibility * Negative Headline Content	0.06 (-0.20 – 0.33)	0.14	0.45	0.657	-0.01 (-0.07 – 0.06)	0.03	-0.25	0.801
Positive Headline Content (Pos vs. Neu)	1.08 (0.85 – 1.32)	0.12	8.93	<0.001	-0.09 (-0.13 – -0.05)	0.02	-3.96	<0.001
Source Credibility * Positive Headline Content	0.00 (-0.28 – 0.28)	0.14	0.00	0.998	-0.02 (-0.07 – 0.04)	0.03	-0.60	0.553
Model Formula	Decision ~ Headline Content * Source Credibility + (S+Neg+S*Neg+Pos+S*Pos subject) + (S+Neg+S*Neg+Pos+S*Pos face)				Latency ~ Headline Content * Source Credibility + (S+Neg+S*Neg+Pos+S*Pos subject) + (S+Neg+S*Neg+Pos+S*Pos face)			

Note. Double bars in random effects terms set correlation parameters to zero. Abbreviations for slopes in the random effects terms: S=Source Credibility, Neg=Negative Headline Content, Pos=Positive Headline Content. Face stands for face stimulus. Number of observations per model: 7146

Pupil size in the social judgment task

In sum, pupil size during social judgments was reduced for faces associated with emotional contents compared to relatively enlarged pupils for neutral contents (Fig. 4; for all plotted time-course b-coefficients please see SI-Fig. S1). Pupil size was larger when news came from distrusted compared to trusted sources but only for neutral contents.

Specifically, pupil size was larger for faces associated with neutral compared to negative headlines between 800ms and 3000ms after stimulus onset (adjusted $ps < .003$) and this effect did not interact with source credibility (adjusted $ps > .3$). Neutral headlines also elicited enlarged pupils compared to positive headlines between 1200ms and 1600ms (adjusted

$ps < .02$) and this effect interacted with source credibility between 800ms and 3000ms (adjusted $ps < .04$). There was no main effect of source credibility (adjusted $ps > .2$).⁴

To test source credibility effects separately in each headline content condition we re-ran the same model with source credibility nested in headline content⁵. Pupil size was larger for neutral headlines from distrusted sources compared to trusted sources between 600ms to 3000ms (adjusted $ps < .05$; Fig. 4C). Source credibility did not modulate pupil size in response to negative or positive headlines (adjusted $ps > .6$; Fig. 4C).

Additionally, to account for their influence on pupil size effects we fit models including the interaction with response latencies (latencies had a positive main effect on pupil size between 1200-3000ms adjusted $ps < .003$; for all plotted model results see SI-Fig. S2, S3). Except the contrast between positive and neutral, all previous effects were robust to controlling for response latencies and there were no significant interactions with response latencies (please see SI).

Figure 4. Pupil size is enlarged for neutral headline content from distrusted sources. Pupil size during social judgments aligns with a cognitive explanation of task-evoked pupil changes according to the load hypothesis rather than an emotional explanation according to the affect hypothesis. **A.** Time-course of pupil size for each content and source credibility (baseline-corrected with 100ms before face onset). **B.** Average pupil size between 600 and 3000ms is larger for neutral compared to emotional headline content. Shown are raincloud plots (Allen et al., 2019) with means and 95% confidence intervals calculated with the *summarySEwithin* function (Morey, 2008) on single trial data, and points, and distributions for data aggregated by subject. **C.** Pupil size is larger for distrusted compared to trusted sources in response to neutral, only. Shown are beta coefficients for the source credibility contrast between 400 and 3000ms after face onset in 200ms bins separately for neutral, negative, and positive headline content. The horizontal bar at the bottom of the plot indicates all time bins with false-discovery rate (FDR) adjusted p -values $< .05$, which was only significant for neutral content, across the indicated time bins (all time bins for negative and positive content were not significant). Shaded bands show standard errors of the mean.

⁴ Model Formula: Pupil $\sim$ Headline Content * Source Credibility + (1 | subject) + (1 | face)

⁵ Model Formula: Pupil $\sim$ Headline Content / Source Credibility + (1 | subject) + (1 | face)

Discussion

Against better knowledge about the lack of credibility of certain news sources, people are affected by social misinformation in headlines. Replicating previous findings (Baum & Abdel Rahman, 2020; 2021), we show that participants rely on the emotional contents of news to make strongly valenced and fast judgments of the persons featured regardless of how credible they find the source. This dominance of emotional contents irrespective of source credibility is in contrast to our original predictions based on dual-process theories assuming controlled and tempered social judgments when people don't trust the source (Baum & Abdel Rahman, 2020; 2021).

Processes reflected in pupil size during news-based social judgments provide novel evidence that helps explain the basic mechanisms of why emotional misinformation may have such dominant effects. Source credibility modulated pupil size with larger pupils for distrusted relative to trusted sources, however only when news contents were neutral. Source credibility did not affect pupil size in response to emotional contents. Instead, emotional contents were associated with smaller pupils relative to neutral contents—even if the emotional news stemmed from distrusted sources.

The pattern of pupil results aligns with a cognitive explanation according to the effort hypothesis rather than an emotional explanation according to the emotion hypothesis (see Fig. 2). First, source credibility affected pupil size which aligns with the effort hypothesis but not the emotion hypothesis. Larger pupils for judgments based on news from distrusted sources may thus reflect the effort associated with uncertainty and the unavailability of strong evidence for social judgments. However, this effect was restricted to neutral contents. For faces associated with emotional headlines no modulation of pupil size by credibility was found. Second, emotional relative to neutral content resulted in smaller pupils which further aligns with the effort hypothesis but not the emotion hypothesis. Smaller pupils for judgments based on emotional news may thus reflect the effortlessness associated with the seemingly strong evidence provided by emotional contents. As neutral news lacks this kind of evidence, the relatively larger pupils suggest that judgments based on neutral contents require more effort. This is further supported by the slow latencies for neutral judgments compared to judgments based on emotional contents.

Previous research is consistent with and helps explain these findings. Increased cognitive effort to process source credibility when news is neutral likely reflects that social judgments from neutral information are associated with uncertainty. Uncertainty was previously found to increase pupil size and the sampling of additional information (Nassar et al., 2012). Uncertainty is further associated with longer decision times and low confidence (e.g., Frömer & Shenhav, 2021), and both were found previously for neutral judgments in the current paradigm (Baum et al., 2022; Baum & Abdel Rahman, 2020; 2021). Therefore, additional information—here in the form of or influenced by source credibility—may have been sought out and processed (Desender et al., 2018), enabling an evaluation of the credibility as seen in the pupil results.

In contrast, reduced effort for judging based on emotional news with no indication of additional efforts towards processing credibility likely reflects fluency and effortlessness (cf. Oppenheimer, 2008) due to the seemingly strong evidence emotional contents provide. Subjective evidence strength is associated with faster decisions and high confidence (Drugowitsch et al., 2012; Frömer & Shenhav, 2021), and both were found previously for judgments from emotional news (Baum et al., 2022; Baum & Abdel Rahman, 2020; 2021). Emotional contexts were previously found to reduce critical semantic analyses (Aristei et al., 2022). Therefore, our results suggest that emotional news yield fluent social judgments without being scrutinized based on source credibility.

Reduced pupil size for emotional compared to neutral stimuli is consistent with previous research. Pupil size was sensitive to cognitive effort rather than emotional processing when similar paradigms demanding cognitive processing were employed, where the emotional relevance of the stimulus was inferred rather than directly observed, e.g., through semantic meaning or associated motivational salience (e.g., Bayer et al. 2011; Hammerschmidt et al., 2018). It is unlikely that neutral headlines resulted in increased arousal-related reactivity compared to emotional headlines in the current study. It is the positive and negative headlines in our paradigm that provoke increased arousal-related emotionality, as seen in pre-ratings of valence and arousal (SI-page 10), as well as in fast, arousal-related electrophysiological brain responses in previous studies (Baum & Abdel Rahman, 2020; 2021; cf. Schindler et al., 2021).

Based on the current results we cannot distinguish if the pupil results reflect effort employed because it is demanded, exerted, or both (e.g., Frömer et al., 2021; van der Wel & van Steenbergen, 2018). Future research is needed to determine, for example, if it is easier to judge based on emotion or if we are less willing to exert mental effort. Here, our conclusion can remain independently: Cognitive resources to evaluate the credibility of social (mis)information are primarily employed when emotional contents providing fluent judgments are not available.

One might argue that although we used well-known media sources and original layouts that closely resemble media content encountered in real-life, our experimental procedure may have lacked ecological validity. While necessary to obtain reliable measurements of the influence of news content and credibility on pupils and social judgments, experimental procedures differ from everyday behaviors. Addressing the concern that results may be different if participants had judged the persons immediately after encountering the news and without doing so repeatedly, we found that the behavioural pattern of results replicates when persons are judged *once* immediately after being exposed to each website (Baum & Abdel Rahman, 2021; see also SI-Table S7). Our findings are therefore unlikely a construct of the experimental setup.

As common in real-life, processing news in our experiment did not include explicit instructions to regard the credibility of the news source, instead participants held distinct opinions about the sources and were free to consider it. Results show that their social impressions and judgments relied on the emotional contents of news, and not the credibility. Initial attempts to intervene with this tendency showed that even if participants explicitly evaluate the sources' credibility before they are exposed to news, the bias towards emotional contents is only weakened for positive news contents whereas the strong impact of negative news contents persists (Baum & Abdel Rahman, 2021). The processes reflected in the pupil size during news-based judgments now help explain why emotional content dominates this way. They suggest that emotional content provides fluency which may discourage effort-demanding, reflective processing that accounts for credibility (e.g., Lieberman, 2007).

Our findings provide a novel contribution to research on cognitive fluency promoting the belief in misinformation. According to the illusory truth effect, information that is more familiar and therefore easier to process is increasingly perceived as true independently of its truth-value (e.g., Pennycook et al., 2018; Stanley et al., 2022; Wang et al., 2016; for a review see Brashier & Marsh, 2020). Emotional contents may provide a similar fluency in face of which employing effort to process credibility is neglected. Hence it is not credibility, but emotion that determines the cognitive effort involved in processing social (mis)information. Future research should investigate how this potential mechanism generalizes to other kinds of information, such as information for which one has pre-existing knowledge, political or health-related information.

In conclusion, the current insights into basic cognitive mechanisms suggest that people are susceptible to emotional misinformation because emotionality yields fluent judgments and

discourages effort-demanding processing of credibility. In perspective, this understanding advances how we identify what interventions may be protective against this bias on an individual level and why they may work by providing testable hypotheses. For example, strategies like friction (“pausing to think”, Fazio, 2020), or engaging in a distrust mindset (Mayo, 2015) may disrupt the potentially misleading fluency of emotional content in favour of investing cognitive resources to evaluate credibility.

References

- Abdel Rahman, R. (2011). Facing good and evil: Early brain signatures of affective biographical knowledge in face recognition. *Emotion*, 11(6), 1397–1405. <http://doi.org/10.1037/a0024717>
- Allen, M., Poggiali, D., Whitaker, K., Marshall, T. R., & Kievit, R. A. (2019). Raincloud plots: a multi-platform tool for robust data visualization. *Wellcome Open Research*, 4, 63. <http://doi.org/10.12688/wellcomeopenres.15191.1>
- Aristei, S., Knoop, C. A., Lubrich, O., Nehrlich, T., Enge, A., Stark, K., Sommer, W., & Abdel Rahman, R. (2022). Affect as Anaesthetic. How emotional contexts modulate the processing of counterintuitive concepts. *Language, Cognition and Neuroscience*. 10.1080/23273798.2022.2085312
- Aston-Jones, G., & Cohen, J. D. (2005). An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance. *Annual Review of Neuroscience*, 28, 403–450. <https://doi.org/10.1146/annurev.neuro.28.061604.135709>
- Bates, D., Kliegl, R., Vasishth, S., & Baayen, R. H. (2015a). Parsimonious mixed models. Available from arXiv:1506.04967 (stat.ME).
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015b). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67(1), 1–48. <http://doi.org/10.18637/jss.v067.i01>
- Baum, J. & Abdel Rahman, R. (2020). Emotional news affects social judgments independent of perceived media credibility. *Social Cognitive and Affective Neuroscience*, 11(6), 1397. <http://doi.org/10.1093/scan/nsaa164>
- Baum, J. & Abdel Rahman, R. (2021). Negative news dominates fast and slow brain responses and social judgments even after source credibility evaluation. *NeuroImage*. <https://doi.org/10.1016/j.neuroimage.2021.118572>
- Baum, J., Frömer, R., & Abdel Rahman, R. (2022). A Bayesian perspective on social decisions based on emotional misinformation. Submitted manuscript.
- Baum, J., Rabovsky, M., Rose, S. B., & Abdel Rahman, R. (2018). Clear judgments based on unclear evidence: Person evaluation is strongly influenced by untrustworthy gossip. *Emotion*, 20(2), 248–260. <http://doi.org/10.1037/emo0000545>
- Bayer, M., Sommer, W., & Schacht, A. (2011). Emotional words impact the mind but not the body: Evidence from pupillary responses. *Psychophysiology*, 48(11), 1554–1562. <http://doi.org/10.1111/j.1469-8986.2011.01219.x>
- Beatty, J. (1982). Task-evoked pupillary responses, processing load, and the structure of processing resources. *Psychological Bulletin*, 91(2), 276–292. <http://doi.org/10.1037/0033-2909.91.2.276>
- Beatty, J., & Lucero-Wagoner, B. (2000). The Pupillary System. Handbook of Psychophysiology Cacioppo, Tassinari & Berntson.
- Benjamini, Y., & Hochberg, Y. (1995). Controlling the False Discovery Rate: A Practical and

- Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society. Series B (Methodological)*, 57(1), 289–300. <http://doi.org/10.2307/2346101?refreqid=search-gateway:025a1890f1052cf99b3585fdaa4b55fd>
- Bliss-Moreau, E., Barrett, L. F., & Wright, C. I. (2008). Individual differences in learning the affective value of others under minimal conditions. *Emotion*, 8(4), 479–493. <http://doi.org/10.1037/1528-3542.8.4.479>
- Bradley, M. M., Miccoli, L., Escrig, M. A., & Lang, P. J. (2008). The pupil as a measure of emotional arousal and autonomic activation. *Psychophysiology*, 45(4), 602–607. <http://doi.org/10.1111/j.1469-8986.2008.00654.x>
- Brashier, N. M., & Marsh, E. J. (2020). Judging Truth. *Annual Review of Psychology*, 71(1), 499–515. <https://doi.org/10.1146/annurev-psych-010419-050807>
- Cunningham, W. A., & Zelazo, P. D. (2007). Attitudes and evaluations: a social cognitive neuroscience perspective. *Trends in Cognitive Sciences*, 11(3), 97–104. <https://doi.org/10.1016/j.tics.2006.12.005>
- Desender, K., Boldt, A., & Yeung, N. (2018). Subjective Confidence Predicts Information Seeking in Decision Making. *Psychological Science*, 29(5), 761–778. <http://doi.org/10.1177/0956797617744771>
- Dimigen, O., Sommer, W., Hohlfeld, A., Jacobs, A. M., & Kliegl, R. (2011). Coregistration of eye movements and EEG in natural reading: Analyses and review. *Journal of Experimental Psychology: General*, 140(4), 552–572. <http://doi.org/10.1037/a0023885>
- Drugowitsch, J., Moreno-Bote, R., Churchland, A. K., Shadlen, M. N., & Pouget, A. (2012). The cost of accumulating evidence in perceptual decision making. *J Neurosci*, 32(11), 3612–3628. doi:10.1523/JNEUROSCI.4010-11.2012
- Ebner, N. C., Riediger, M., & Lindenberger, U. (2010). FACES—A database of facial expressions in young, middle-aged, and older women and men: Development and validation. *Behavior Research Methods*, 42(1), 351–362. <http://doi.org/10.3758/BRM.42.1.351>
- Ecker, U. K. H., Lewandowsky, S., Cook, J., Schmid, P., Fazio, L. K., Brashier, N., Kendeou, P., Vraga, E. K., & Amazeen, M. A. (2022). The psychological drivers of misinformation belief and its resistance to correction. *Nature Reviews Psychology*, 1(1), 13–29. <https://doi.org/10.1038/s44159-021-00006-y>
- Engelhardt, P. E., Ferreira, F., & Patsenko, E. G. (2010). Pupillometry reveals processing load during spoken language comprehension. *Quarterly Journal of Experimental Psychology*, 63(4), 639–645. <https://doi.org/10.1080/17470210903469864>
- Ellsworth, P. C., & Scherer, K. R. (2003). Appraisal processes in emotion. In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Series in affective science*. (pp. 572–595). New York, NY, US: Oxford University Press.
- Fazio, L. (2020). Pausing to consider why a headline is true or false can help reduce the sharing of false news. *Harvard Kennedy School Misinformation Review*, 1(2), 1–8. <https://doi.org/10.37016/mr-2020-009>
- FeldmanHall, O., & Shenhav, A. (2019). Resolving uncertainty in a social world. *Nature Human Behaviour*, 11(5), 419. <http://doi.org/10.1038/s41562-019-0590-x>
- Ferrari, C., Oh, D., Labbree, B. P., & Todorov, A. (2020). Learning the affective value of people: More than affect-based mechanisms. *Acta Psychologica*, 203, 103011. <http://doi.org/10.1016/j.actpsy.2020.103011>
- Frömer, R., Lin, H., Dean Wolf, C. K., Inzlicht, M., & Shenhav, A. (2021). Expectations of reward and efficacy guide cognitive control allocation. *Nature Communications*, 12(1), 1030. doi:10.1038/s41467-021-21315-z
- Frömer, R., & Shenhav, A. (2021). Filling the gaps: Cognitive control as a critical lens for understanding mechanisms of value-based decision-making. *Neuroscience &*

- Biobehavioral Reviews*, 104483. <https://doi.org/10.1016/j.neubiorev.2021.12.006>
- Frömer, R., Maier, M., & Abdel Rahman, R. (2018). Group-Level EEG-Processing Pipeline for Flexible Single Trial-Based Analyses Including Linear Mixed Models. *Frontiers in Neuroscience*, 12, 970. <http://doi.org/10.3389/fnins.2018.00048>
- Gawronski, B., & Bodenhausen, G. V. (2006). Associative and propositional processes in evaluation: An integrative review of implicit and explicit attitude change. *Psychological Bulletin*, 132(5), 692–731. <https://doi.org/10.1037/0033-2909.132.5.692>
- Gilzenrat, M. S., Nieuwenhuis, S., Jepma, M., & Cohen, J. D. (2010). Pupil diameter tracks changes in control state predicted by the adaptive gain theory of locus coeruleus function. *Cognitive, Affective, & Behavioral Neuroscience* 2010 10:2, 10(2), 252–269. <https://doi.org/10.3758/CABN.10.2.252>
- Granholm, E., & Steinhauser, S. R. (2004). Pupillometric measures of cognitive and emotional processes. *International Journal of Psychophysiology*, 52(1), 1–6. <https://doi.org/10.1016/j.ijpsycho.2003.12.001>
- Green, P., & MacLeod, C. J. (2016). SIMR: an R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, 7(4), 493–498. <http://doi.org/10.1111/2041-210X.12504>
- Hammerschmidt, W., Kagan, I., Kulke, L., & Schacht, A. (2018). Implicit reward associations impact face processing: Time-resolved evidence from event-related brain potentials and pupil dilations. *NeuroImage*, 179, 557–569. <http://doi.org/10.1016/j.neuroimage.2018.06.055>
- Just, M. A., Carpenter, P. A., & Miyake, A. (2003). Neuroindices of cognitive workload: Neuroimaging, pupillometric and event-related potential studies of brain work. *Theoretical Issues in Ergonomics Science*, 4(1–2), 59–88. <https://doi.org/10.1080/14639220210159735>
- Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, 58(9), 697–720. <http://doi.org/10.1037/0003-066X.58.9.697>
- Kahneman, D., Tursky, B., Shapiro, D., & Crider, A. (1969). Pupillary, heart rate, and skin resistance changes during a mental task. *Journal of Experimental Psychology*, 79(1 PART 1), 164–167. <https://doi.org/10.1037/h0026952>
- Kozyreva, A., Lewandowsky, S., & Hertwig, R. (2020). Citizens Versus the Internet: Confronting Digital Challenges With Cognitive Tools. *Psychological Science in the Public Interest*, 21(3), 103–156. <https://doi.org/10.1177/1529100620946707>
- Kret, M. E., Roelofs, K., Stekelenburg, J. J., & de Gelder, B. (2013). Emotional signals from faces, bodies and scenes influence observers' face expressions, fixations and pupil-size. *Frontiers in Human Neuroscience*, 7. <http://doi.org/10.3389/fnhum.2013.00810>
- Kret, M. E., & Sjak-Shie, E. E. (2018). Preprocessing pupil size data: Guidelines and code. *Behavior Research Methods*, 51(3), 1336–1342. <http://doi.org/10.3758/s13428-018-1075-y>
- Kuchinke, L., Trapp, S., Jacobs, A. M., & Leder, H. (2009). Pupillary Responses in Art Appreciation: Effects of Aesthetic Emotions. *Psychology of Aesthetics, Creativity, and the Arts*, 3(3), 156–163. <https://doi.org/10.1037/a0014464>
- Kuniecki, M., Wołoszyn, K., Domagalik, A., & Pilarczyk, J. (2018). Disentangling brain activity related to the processing of emotional visual information and emotional arousal. *Brain Structure and Function*, 223(4), 1589–1597. <https://doi.org/10.1007/s00429-017-1576-y>
- Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTestPackage: Tests in Linear Mixed Effects Models. *Journal of Statistical Software*, 82(13), 1–26. <http://doi.org/10.18637/jss.v082.i13>
- Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., & van Knippenberg,

- A. (2010). Presentation and validation of the Radboud Faces Database. *Cognition & Emotion*, 24(8), 1377–1388.
- Liddell, B. J., Brown, K. J., Kemp, A. H., Barton, M. J., Das, P., Peduto, A., Gordon, E., & Williams, L. M. (2005). A direct brainstem-amygdala-cortical “alarm” system for subliminal signals of fear. *NeuroImage*, 24(1), 235–243. <https://doi.org/10.1016/j.neuroimage.2004.08.016>
- Lieberman, M. D. (2007). Social Cognitive Neuroscience: A Review of Core Processes. *Annual Review of Psychology*, 58(1), 259–289. <http://doi.org/10.1146/annurev.psych.58.110405.085654>
- Lorenz-Spreen, P., Lewandowsky, S., Sunstein, C. R., & Hertwig, R. (2020). How behavioural sciences can promote truth, autonomy and democratic discourse online. *Nature Human Behaviour*, 4(11), 1102–1109. <https://doi.org/10.1038/s41562-020-0889-7>
- Mather, M., Clewett, D., Sakaki, M., & Harley, C. W. (2016). Norepinephrine ignites local hotspots of neuronal excitation: How arousal amplifies selectivity in perception and memory. *Behavioral and Brain Sciences*, 39(2016). <https://doi.org/10.1017/S0140525X15000667>
- Mathôt, S., Fabius, J., Van Heusden, E., & Van der Stigchel, S. (2018). Safe and sensible preprocessing and baseline correction of pupil-size data. *Behavior Research Methods*, 50(1), 94–106. <http://doi.org/10.3758/s13428-017-1007-2>
- Mayo, R. (2015). Cognition is a matter of trust: Distrust tunes cognitive processes. *European Review of Social Psychology*, 26(1), 283–327. <https://doi.org/10.1080/10463283.2015.1117249>
- Metzger, M. J., & Flanagin, A. J. (2013). Credibility and trust of information in online environments: The use of cognitive heuristics. *Journal of Pragmatics*, 59, 210–220. <http://doi.org/10.1016/j.pragma.2013.07.012>
- Morey, R. D. (2008) Confidence intervals from normalized data: A correction to Cousineau (2005). *Tutorials in Qualitative Methods for Psychology* 4: 61–64.
- Nassar, M. R., Rumsey, K. M., Wilson, R. C., Parikh, K., Heasly, B., & Gold, J. I. (2012). Rational regulation of learning dynamics by pupil-linked arousal systems. *Nature Neuroscience*, 15(7), 1040–1046. doi:10.1038/nn.3130
- Nuthmann, A., & Van Der Meer, E. (2005). Time’s arrow and pupillary response. *Psychophysiology*, 42(3), 306–317. <https://doi.org/10.1111/j.1469-8986.2005.00291.x>
- Oliva, M., & Anikin, A. (2018). Pupil dilation reflects the time course of emotion recognition in human vocalizations. *Scientific Reports*, 8(1), 1–10. <https://doi.org/10.1038/s41598-018-23265-x>
- Oppenheimer, D. M. (2008). The secret life of fluency. *Trends in Cognitive Sciences*, 12(6), 237–241. <https://doi.org/10.1016/J.TICS.2008.02.014>
- Papesh, M. H., & Goldinger, S. D. (2012). Pupil-BLAH-metry: Cognitive effort in speech planning reflected by pupil dilation. *Attention, Perception, and Psychophysics*, 74(4), 754–765. <https://doi.org/10.3758/s13414-011-0263-y>
- Peinkhofer, C., Knudsen, G. M., Moretti, R., & Kondziella, D. (2019). Cortical modulation of pupillary function: Systematic review. *PeerJ Computer Science*, 2019(7), e6882--38. <https://doi.org/10.7717/peerj.6882>
- Pennycook, G., Cannon, T. D., & Rand, D. G. (2018). Prior exposure increases perceived accuracy of fake news. *Journal of Experimental Psychology: General*, 147(12), 1865–1880. <https://doi.org/10.1037/xge0000465>
- Pennycook, G., Epstein, Z., Mosleh, M., Arechar, A. A., Eckles, D., & Rand, D. G. (2021). Shifting attention to accuracy can reduce misinformation online. *Nature*, 592(April). <https://doi.org/10.1038/s41586-021-03344-2>

- Pennycook, G., & Rand, D. G. (2019). Fighting misinformation on social media using crowdsourced judgments of news source quality. *Proceedings of the National Academy of Sciences*, 116(7), 2521–2526. <http://doi.org/10.1073/pnas.1806781116>
- Pennycook, G., & Rand, D. G. (2021). The Psychology of Fake News. *Trends in Cognitive Sciences*, 25(5), 388–402. <https://doi.org/10.1016/j.tics.2021.02.007>
- Prehn, K., Heekeren, H. R., & van der Meer, E. (2011). Influence of affective significance on different levels of processing using pupil dilation in an analogical reasoning task. *International Journal of Psychophysiology*, 79(2), 236–243. <http://doi.org/10.1016/j.ijpsycho.2010.10.014>
- Raisig, S., Welke, T., Hagedorf, H., & Van Der Meer, E. (2007). Investigating dimensional organization in scripts using the pupillary response. *Psychophysiology*, 44(6), 864–873. <https://doi.org/10.1111/J.1469-8986.2007.00592.X>
- Schad, D. J., Vasishth, S., Hohenstein, S., & Kliegl, R. (2020). How to capitalize on a priori contrasts in linear (mixed) models_ A tutorial. *Journal of Memory and Language*, 110, 104038. <http://doi.org/10.1016/j.jml.2019.104038>
- Scherer, K. R. (2001). Appraisal considered as a process of multilevel sequential checking. In K. R. Scherer, A. Schorr, & T. Johnstone (Eds.), *Series in affective science*. (pp. 92–120). New York, NY, US: Oxford University Press.
- Shechter, A., & Share, D. L. (2021). Keeping an Eye on Effort: A Pupillometric Investigation of Effort and Effortlessness in Visual Word Recognition. *Psychological Science*, 32(1), 80–95. <https://doi.org/10.1177/0956797620958638>
- Sirois, S., & Brisson, J. (2014). Pupillometry. *Wiley Interdisciplinary Reviews: Cognitive Science*, 5(6), 679–692. <https://doi.org/10.1002/WCS.1323>
- Stanley, M. L., Whitehead, P. S., Marsh, E. J., & Seli, P. (2022). Prior exposure increases judged truth even during periods of mind wandering. *Psychonomic Bulletin & Review*. <https://doi.org/10.3758/S13423-022-02101-4>
- Steinhauer, S. R., Siegle, G. J., Condray, R., & Pless, M. (2004). Sympathetic and parasympathetic innervation of pupillary dilation during sustained processing. *International Journal of Psychophysiology*, 52(1), 77–86. <https://doi.org/10.1016/j.ijpsycho.2003.12.005>
- Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review*, 8(3), 220–247. https://doi.org/10.1207/s15327957pspr0803_1
- Suess, F., Rabovsky, M., & Abdel Rahman, R. (2015). Perceiving emotions in neutral faces: expression processing is biased by affective person knowledge. *Social Cognitive and Affective Neuroscience*, 10(4), 531–536. <http://doi.org/10.1093/scan/nsu088>
- Treen, K. M. d. I., Williams, H. T. P., & O'Neill, S. J. (2020). Online misinformation about climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 11(5), 1–20. <https://doi.org/10.1002/wcc.665>
- van der Meer, E., Beyer, R., Horn, J., Foth, M., Bornemann, B., Ries, J., Kramer, J., Warmuth, E., Heekeren, H. R., & Wartenburger, I. (2010). Resource allocation and fluid intelligence: Insights from pupillometry. *Psychophysiology*, 47(1), 158–169. <https://doi.org/10.1111/j.1469-8986.2009.00884.x>
- van der Meer, E., Friedrich, M., Nuthmann, A., Stelzel, C., & Kuchinke, L. (2003). Picture-word matching: Flexibility in conceptual memory and pupillary responses. *Psychophysiology*, 40(6), 904–913. <https://doi.org/10.1111/1469-8986.00108>
- van der Wel, P., & van Steenbergen, H. (2018). Pupil dilation as an index of effort in cognitive control tasks: A review. *Psychonomic Bulletin & Review*, 25(6), 2005–2015. <http://doi.org/10.3758/s13423-018-1432-y>
- Verney, S. P., Granholm, E., & Marshall, S. P. (2004). Pupillary responses on the visual

- backward masking task reflect general cognitive ability. *International Journal of Psychophysiology*, 52(1), 23–36. <https://doi.org/10.1016/j.ijpsycho.2003.12.003>
- Vosoughi, S., Roy, D., & Aral, S. (2018). The spread of true and false news online. *Science*, 359(6380), 1146–1151. <http://doi.org/10.1126/science.aap9559>
- Wang, W.-C., Brashier, N. M., Wing, E. A., Marsh, E. J., & Cabeza, R. (2016). On Known Unknowns: Fluency and the Neural Mechanisms of Illusory Truth. *Journal of Cognitive Neuroscience*, 28(5), 739–746. https://doi.org/10.1162/jocn_a_00923
- Yih, J., Sha, H., Beam, D. E., Parvizi, J., & Gross, J. J. (2018). Reappraising faces: effects on accountability appraisals, self-reported valence, and pupil diameter. *Cognition & Emotion*, 33(5), 1041–1050. <http://doi.org/10.1080/02699931.2018.1507999>
- Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, 46(3), 441–517. <https://doi.org/10.1006/jmla.2002.2864>

Author's contribution

JB and RAR designed research; JB, RF, and RAR wrote the paper; JB performed research and JB and RF analyzed data.

Acknowledgements

We thank Elke van der Meer for valuable advice about pupillometry as a measure of cognitive-emotional processes. We thank Guido Kiecker for technical support and Franziska Glogau, Nathalie Königer, and Kirsten Stark for assisting in data acquisition, Philip Rausch and Kirsten Stark for help with pupil data preprocessing.

Funding

This work was supported by a PhD scholarship of Studienstiftung des Deutschen Volkes to Julia Baum and German Research Foundation grant AB 277-6 to Rasha Abdel Rahman

Data Availability

Data and code is available to the reviewers and upon publication.

Conflict of Interest

The authors declare no conflicts of interest with respect to authorship or the publication of this article.