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EDITORIAL

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Why is fake news so fascinating to the brain?

> There has been more new error propagated by the press in the last ten years than in a hundred years before 1798.
>
> John Adams, *A Defence of the Constitutions of Government of the United States of America*

1 | FAKE NEWS IN HISTORY: FROM POLITICS TO BIOMEDICAL RESEARCH

The advent of a new era of false information can be traced back to 2016 when the Oxford Dictionary designated "post-truth" as the key word of the year, defining it as "circumstances in which objective facts are less influential, in the formation of public opinion, than an appeal to the emotions and personal convictions." However, fake news is by no means a recent phenomenon, featuring a long history that has evolved over time. As an example, the *Donation of Constantine*, an imperial decree issued by the 4th-century emperor Constantine to purportedly transfer control over the Western Roman Empire to the Pope, was conclusively exposed as a forgery in the 15th century (Ecker et al., 2022; Ginzburg, 2012). Originally documented in the 1890s, fake news gained momentum in the late 19th century when newspapers started to disseminate false and distorted news articles focused on sensationalism. Disregarding the various forms of political propaganda spread vertically by illiberal regimes as disinformation (Tandoc et al., 2018), this so-called "yellow journalism" subsequently declined in popularity until the recent revival of interest caused by the development of web-based fake news (Balnaves, 2020; Creech & Roessner, 2018).

The fake news disseminated today differs substantially from those previously propagated, as they are driven by social media, making them instantly available worldwide at a previously unprecedented speed of propagation. Present-day fake news generates an "information disorder" in which news satire, parody, fabrication, manipulation, advertising, and propaganda are blended and denoted using a threefold distinction: (1) misinformation, that is, unintentional incorrect information; (2) disinformation, that is, the deliberate fabrication and/or sharing of false information; (3) mal-information, that is, deliberate publication of true private/sensitive information with change of context (cherry picking).

In addition to the political context, the scientific milieu represents another significant field in which fake news is frequently published. This is particularly true with regard to topics such as vaccines, genetically modified organisms (GMOs), use of stem cells, animal experimentation, climate change, renewable energies, and the so-called alternative therapies for oncological and neurodegenerative diseases (van der Linden, 2022). Substantial amounts of false information relate to (1) the existence of impure vaccine constituents that ranged from poisonous synthetic metals to aborted foetuses (Kata, 2010; Wolfe et al., 2002); (2) the fraud on the relation between vaccines and autism linked disorders, which was propagated by A. Wakefield et al. (1998). In a case series published in *The Lancet*, Wakefield suggested that the measles mumps and rubella (MMR) vaccine could be the cause of pervasive developmental disorders and intestinal abnormalities. Although this article was later retracted by the journal, it had a pervasive negative influence in the field and, more importantly, in the public; (3) the Italian and German scandals surrounding the infusion of fake stem-cells to treat paediatric neurodegenerative diseases (respectively, "Stamina 'method'" and "XCell procedure"). In particular, Stamina was an unproven treatment advertised in Italy from 2007 to 2014, based on alleged conversion of mesenchymal stem cells into neurons. In the face of the pro-Stamina street demonstrations and the strong media pressure, it was even proposed a clinical trial despite the objections of the global scientific community. Only in 2014, Stamina was discontinued, and a year later, its promoter was convicted of criminal charges (Abbott, 2011; Cattaneo & Corbellini, 2014); (4) animal activist disinformation campaigns and illegal actions targeting animal facilities and scientists. Recent examples reported worldwide include the case of Nikos Logothetis at Max Planck, who was dismissed by the German court after being accused of animal-welfare

violations related to monkeys used in neurophysiology research (Abbott, 2018), or the Italian neuroscientists Marco Tamietto and Luca Bonini threatened by animal rights groups for experiments that also involved macaque monkeys in studies seeking treatments for patients who suffer damage to visual cortex (Abbott, 2019).

2 | PRINCIPLES OF BRAIN FUNCTIONING INVOLVED IN PROCESSING FAKE NEWS

Psychology and neuroscience are making great strides in revealing inferences and motives that craft our construal of reality (Brashier & Marsh, 2020; Pennycook & Rand, 2021). Complex cognitive tasks, such as discerning truth from falsehood, are also influenced by phylogenetically ancient brain structures engaged in affect, reward, and social interaction, or in the formation of coalitional alliances (Van Bavel & Pereira, 2018). This happens because newer brain structures capable of increasingly complex cognitive functions are not simply superimposed upon existing ones (Paul et al., 2020). Indeed, motivated cognition pervades information processing (Hughes & Zaki, 2015) with, for example, the amygdala responding differently to facial expressions depending on group membership (Bagnis et al., 2020). This and other subcortical structures also exert bottom-up modulation over brain activity at various processing stages, from early visual areas to fronto-parietal cortices that direct attention toward salient environmental events (Tamietto et al., 2005; Tamietto & de Gelder, 2010; Vuillumier, 2005).

Activation of dopamine-controlled reward pathways has been described when sharing information with others, thereby facilitating appetitive behavioural arousal (Tamir & Mitchell, 2012). Several preclinical studies have shown that novel and salient stimuli increase extracellular dopamine levels in the Nucleus Accumbens (NAcc) and medial Pre-Frontal Cortex (mPFC) (Bassareo et al., 2002; Ikemoto & Panksepp, 1999). Moreover, midbrain catecholamine cell groups of monkeys, dorsal to lateral substantia nigra (pars-compacta) and ventral tegmental area (VTA), fire when an unexpected reward occurs, do not respond when a fully predicted reward is presented, and decrease their firing activity when a predicted reward is omitted (Mirenowicz & Schultz, 1996; Schultz, 2016). Additional causal evidence indicates that lesions of the dopaminergic pre-limbic and infralimbic cortices, which in rodents correspond to mPFC, eliminate the impact of novelty in reward (Bimpisidis et al., 2013).

Since fake news is usually conveyed within a salient context, it likely produces a rise in dopamine release in NAcc and stimulates an approach response. Fake news is appealing and generated with the aim of being disruptive and unexpected, hence capturing attention. In an fMRI study, the "Likes" posted by adolescents on social media were associated with activations of the ventral striatum and ventro-medial PFC, whereas receiving feedback of "Likes" engaged the dorsal and ventral striatum, thalamus, VTA, and PFC (Sherman et al., 2018). In general, heightened reliance on emotionality predicts greater belief in fake, but not real, news (Martel et al., 2020). On the contrary, activity in areas related to deeper information-processing, such as the orbito-frontal cortex (OFC) and lateral PFC, is reduced during biased judgements and correlates negatively with amygdala response (Roy et al., 2012; Sharot et al., 2011). The OFC encodes the value of competing goals (e.g., identity vs. accuracy and truth discernment) and integrates affective and contextual information for decision-making, while the lateral PFC is engaged in response selection (Pessoa, 2008).

Susceptibility to fake news may originate from how the brain incorporates expectations in the interpretation of incoming information based on priors and how it deals with conflict monitoring (Brashier & Marsh, 2020). Consistency with memory, owing to feelings of familiarity, is one heuristic used to infer truth. Repeated claims seem truer than a new one, as reflected in increased activity in the perirhinal cortex, a region implicated in other familiarity effects such as priming (Wang et al., 2016). Probability-modulated responses are also observed in the parietal cortex and PFC, and expectations steer how information is processed (Summerfield & de Lange, 2014). For example, we tend to discount information that undermines past judgments, underlining the importance of memory. A recent study has found that this confirmation bias is related to activity in the mPFC and is selective for others' disconfirming options, but unaltered when opinions confirm previous choices (Kappes et al., 2020). The authors found that the mPFC and anterior cingulate cortex (ACC) are implicated in monitoring and signalling conflict and in prediction errors, two functions needed to curb information processing along lines that preserve identity coherence and sense of continuity.

Social expectations and group membership are fundamental motifs that influence how we approach information, hence endorsing the sustaining of fake news. Social brain areas include the PFC and temporo-parietal cortices, ACC, and posterior cingulate/precuneus, together with subcortical areas such as the bed nucleus of the stria terminalis and lateral septum (Eslinger et al., 2021). Peptides like arginine-vasopressin and oxytocin are known to modulate human social behaviour and actively influence responses in these brain areas (Albers, 2015), including

vicarious emotions experienced by observing other members of our social group (Eslinger et al., 2021).

A further element under consideration is the evaluation of source credibility. When asked to evaluate the credibility of a source of information during EEG, significant activations in the inferior parietal lobule, the insula, and the ACC of participating individuals have been reported (Kawiak et al., 2020). This suggests that the process of credibility evaluation requires two mechanisms similar to those involved in complementary processes: (1) decision-making under emotionally charged situations, as in moral dilemmas (Harlé et al., 2012; Stern et al., 2010), and (2) the assessment of probability for rewards under high uncertainty (Stern et al., 2010).

Acceptance of fake news therefore is a highly complex phenomenon that includes numerous elements such as memory, reward, novelty, and social interaction. Moreover, the information processing required in discriminating truth from falsehood is particularly complex and involves phylogenetically ancient brain areas such as amygdala, NAcc, and VTA along with higher order association cortices.

3 | POTENTIAL INTERVENTIONS AND DE-BIASING STRATEGIES

How can neuroscience help individuals to identify fake news and counter misinformation? By providing a mechanistic understanding of the principles of functioning involved in processing fake news, neuroscience can break down these processes based on dissociations in brain networks and contribute to devising interventions that tend to align beliefs with verified facts.

Devising principled strategies to counter fake news is timely, as short exposure to fake news (5 min) modifies not only attitudes but also unconscious behaviours measured by means of neuropsychological tests of cognitive and motor functions (Bastick, 2021). The veracity of headlines has little effect on sharing intentions, despite having a marked effect on judgments of accuracy (Peenycook et al., 2021). Notably, by shifting attention to accuracy, the quality of news that people subsequently share increases. The latter and similar interventions should be measurable based on enhanced activity in fronto-parietal attentional network and, in principle, might also involve selective stimulation achievable by means of transcranial magnetic stimulation (TMS).

Countering misconception by fact-checking may temporarily reduce belief, but corrective messages quickly fade from memory. In reality, people concurrently store both corrections and the original misinformation, although the more recent correction is forgotten at a faster rate than the older misconception, as indicated by activity in the left angular gyrus and bilateral precuneus (Gordon et al., 2019). However, the provision of news headlines fact-checks (debunking) enhances a subsequent ability to discern the truth more effectively than by merely providing the same information during (labelling) or prior to (prebunking) exposure (Brashier & Marsh, 2020).

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CONFLICT OF INTEREST

The authors have no conflict of interest.

PEER REVIEW

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