Instytut Farmakologii im. Jerzego Maja Polskiej Akademii Nauk

Rozprawa Doktorska

Psychologiczne, poznawcze i farmakologiczne korelaty podatności na (dez)informację u ludzi

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#Gratitude

Spis Treści

Spis artykułów wchodzących w skład rozprawy doktorskiej

1. Piksa M, Noworyta K, Gundersen A, Kunst J, Morzy M, Piasecki J, Rygula R. Are we willing to share what we believe is true? Factors influencing susceptibility to fake news. Frontiers in Psychiatry. 2023.
   doi:10.3389/fpsyt.2023.1165103.

   Impact Factor: 4.7
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2. Piksa M, Noworyta K, Piasecki J, Gwiazdzinski P, Gundersen AB, Kunst J, Rygula R. Cognitive Processes and Personality Traits Underlying Four Phenotypes of Susceptibility to (Mis)Information. Frontiers in Psychiatry. 2022.
   doi:10.3389/fpsyt.2022.912397.

   Impact Factor: 4.7
   Punkty ministerialne: 140

3. Piksa M, Noworyta K, Piasecki J, Gundersen A, Kunst J, Morzy M, Rygula R. Research Report: A Link between Sertraline Treatment and Susceptibility to (Mis)information. ACS Chemical Neuroscience. 2024.
   doi:10.1021/acschemneuro.3c00825

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Streszczenie

W dobie cyfrowej dezinformacja stała się zagrożeniem globalnym, wpływającym na decyzje polityczne, zdrowotne oraz społeczne. W związku z powyższym, celem niniejszej pracy doktorskiej było badanie mechanizmów regulujących podatność na dezinformację. W swojej pracy skupiłem się na dezinformacji związanej z pandemią Covid-19, co stanowiło doskonały kontekst do analizy tego zjawiska. W ramach współpracy z Uniwersytetem w Oslo opracowałem również skalę podatności na dezinformację, wykorzystującą nagłówki stylizowane na posty z platformy Facebook.

W pierwszym badaniu, wchodzącym w skład niniejszej rozprawy doktorskiej, opublikowanym w czasopiśmie Frontiers in Psychiatry (2023), analizowałem wpływ weryfikowalnej prawdziwości informacji, zgodności z przekonaniami oraz stylu prezentacji, na ocenę prawdziwości oraz zaangażowanie behawioralne odbiorców informacji. Wyniki wskazują, że chociaż weryfikowalna prawdziwość informacji była kluczowa dla oceny prawdziwości, to właśnie zgodność informacji z przekonaniami odbiorców najsilniej wpływała na chęć dzielenia się jej treścią.

Drugie badanie, również opublikowane na łamach Frontiers in Psychiatry (2022), miało na celu zidentyfikowanie indywidualnych różnic w procesach poznawczych i cechach osobowości, wpływających na podatność na dezinformację. Wyróżniłem cztery fenotypy podatności na (dez)informację: wątpiących, konsumentów, wiedzących i naiwniaków, różniące się pod względem procesów

poznawczych oraz cech osobowości, takich jak lękliwość i narcyzm czy wrażliwość na wzmocnienia.

W trzecim badaniu, opublikowanym w czasopiśmie ACS Chemical Neuroscience (2024), badałem wpływ sertraliny – leku przeciwdepresyjnego – na podatność na dezinformację. Wyniki wskazują, że osoby przyjmujące sertralinę były bardziej skłonne do dzielenia się informacjami, niezależnie od ich prawdziwości, co sugeruje niespecyficzny wpływ serotoniny na przetwarzanie informacji.

Podsumowując, przedstawione badania ukazują złożone mechanizmy podatności na dezinformację, łącząc perspektywy psychologiczne, poznawcze i medyczne. Wyniki stanowią fundament do dalszych badań nad efektywnymi metodami przeciwdziałania dezinformacji oraz zrozumienia jej roli w kontekście psychiatrycznym.

Abstract

In the digital age, disinformation has become a global threat, influencing political, health, and social decisions. The aim of this doctoral dissertation was to explore the mechanisms underlying susceptibility to misinformation. I focused on misinformation related to the Covid-19 pandemic, which provided an ideal context for analyzing this phenomenon. In collaboration with the University of Oslo, I also developed a Disinformation Susceptibility Scale, utilizing headlines styled as Facebook posts.

In the first study, included in this dissertation, and published in Frontiers in Psychiatry (2023), I analyzed the impact of verifiable truthfulness, alignment with recipients' beliefs, and presentation style on users' assessment of veracity, and behavioral engagement with an information. The results indicated that while truthfulness was crucial for the veracity rating, the alignment with recipients' beliefs had the strongest influence on their willingness to share the content.

The second study, included in this dissertation, also published in Frontiers in Psychiatry (2022), aimed to identify individual differences in cognitive processes and personality traits that influence susceptibility to misinformation. For this, I distinguished four phenotypes of susceptibility to (mis)information: doubters, consumers, knowers, and duffers, each differing in cognitive processes and personality traits such as anxiety, narcissism, and sensitivity to reinforcement.

In the third study, published in ACS Chemical Neuroscience (2024), I examined the impact of sertraline, an antidepressant, on susceptibility to misinformation. The obtained results suggest that individuals taking sertraline are more likely to share information regardless of its truthfulness, indicating a non-specific influence of serotonin on information processing.

In summary, the presented studies reveal the complex mechanisms of susceptibility to misinformation, combining psychological, cognitive, and medical perspectives. The results lay a foundation for further research into effective methods of countering misinformation and understanding its role in a psychiatric context.

„If you don't have facts, you can't have truth. Without truth, you can't have trust. Without these three, we have no shared reality. We cannot attempt to solve any problem. You can't have democracy if you don't have integrity of facts."

Maria Ressa

Laureatka Pokojowej Nagrody Nobla

Wprowadzenie

Rozprzestrzenianie się nieprawdziwych informacji (dezinformacji/*fake news*) w przestrzeni publicznej może mieć szkodliwe konsekwencje, zarówno dla życia jednostek, jak i sprawnego funkcjonowania całych społeczeństw. Podważanie zasadności wykonywania szczepień, kwestionowanie zmian klimatycznych czy istnienia pandemii, ale także przebieg wydarzeń politycznych, takich jak wybory prezydenckie w Stanach Zjednoczonych z 2016 roku czy referendum w sprawie wyjścia Wielkiej Brytanii z Unii Europejskiej, z całą mocą pokazały destrukcyjną siłę zorganizowanych kampanii dezinformacyjnych (Greifeneder et al., 2020).

Ponieważ nie wszyscy w równym stopniu poddają się oddziaływaniu dezinformacji (van der Linden, 2022), postuluje się istnienie różnic indywidualnych warunkujących podatność na *fake newsy* (Geers et al., 2022). Dlatego niezwykle istotnym wydaje się znalezienie odpowiedzi na pytanie: jakie procesy poznawcze mogą brać udział w kształtowaniu podatności czy odporności na dezinformację? Ponadto, z uwagi na interaktywny charakter przetwarzania informacji, istotnymi czynnikami modulującymi podatność na dezinformację mogą być również właściwości samej informacji, takie jak sposób i styl przedstawienia czy spójność informacji ze światopoglądem odbiorcy (van der Linden and Rozenbeek, 2020). Z tych powodów w badaniu zagadnienia podatności na dezinformację należy poświęcić uwagę zarówno mechanizmom poznawczym i cechom osobowościowym zaangażowanym w postrzeganie rzeczywistości i przetwarzanie informacji, jak

również charakterystycznym cechom samej informacji (Figueiredo, 2006; Simons et al., 2017).

Dotychczasowe badania jednoznacznie wskazują na istnienie silnej korelacji między podatnością na dezinformację i preferencją do korzystania z intuicyjnego systemu przetwarzania informacji, czyli tendencją do szybkiego, powierzchownego i bezrefleksyjnego wnioskowania (Pennycook and Rand, 2019; Bago et al., 2020). W przeciwieństwie do systemu analitycznego, system intuicyjny działa w oparciu o heurystyki, czyli uproszczone wzorce wnioskowania, sprzyjające powstawaniu błędów i zniekształceń poznawczych (Kahneman, 2011). Jako że nasilone zniekształcenia poznawcze leżą u podłoża wielu chorób psychicznych takich jak depresja (Joormann and Siemer, 2011), zaburzenia osobowości (Puri et al., 2018), lękowe (Kimbrel et al., 2012), czy psychotyczne (Bowins, 2012), to występowanie podobnych mechanizmów leżących u podłoża podatności na dezinformację mogłoby sugerować, że ta zwiększona podatność jest również symptomem lub przejawem zaburzenia psychicznego (Taurino et al., 2023).

Należy również podkreślić, że przetwarzanie informacji, a tym samym dezinformacji, jest ściśle związane z mechanizmami ośrodkowego układu nerwowego (Nichols and Newsome, 1999), zwłaszcza o podłożu serotoninowym. Na przykład, obniżenie poziomu prekursora serotoniny tryptofanu, skutkujące zmniejszeniem poziomu serotoniny, zwiększało wrażliwość na negatywne informacje zwrotne (Evers et al., 2005). Natomiast podanie fenfluraminy (substancji uwalniającej serotoninę) redukowało wrażliwość na negatywne informacje zwrotne (Colwell et al., 2024).

Podobną zależność zaobserwowano u pacjentów leczonych paroksetyną (selektywnym inhibitorem wychwytu zwrotnego serotoniny), którzy również byli mniej wrażliwi ten typ informacji w porównaniu do pacjentów nie leczonych i grupy kontrolnej (Herzallah et al., 2013). Z tego powodu istotnym przedmiotem badań nad mechanizmami warunkującymi podatność na dezinformację jest poszukiwanie jej biochemicznych korelatów. Pełne zrozumienie tych mechanizmów zdaje się być kluczowym etapem w opracowaniu skutecznych metod zapobiegania, czy wręcz immunizacji jednostek przeciwko dezinformacji (Basol et al., 2020).

Podatność na dezinformację

W 2020 roku Światowa Organizacja Zdrowia wypowiedziała wojnę infodemii (*ang. infodemic*) (Zarocostas, 2020). Analogicznie do pandemii, infodemia to problem ogólnoświatowy, którego „patogenem" jest zaburzona informacja (ang. *information disorder*). O zaburzonej informacji można mówić wtedy, gdy występuje przynajmniej jedno z dwóch kryteriów: fałszywość i/lub propagacja w celu wyrządzenia szkody (Wardle and Derakhshan, 2017) (Tabela 1). W badaniach na potrzeby tej rozprawy, dla uproszczenia metodologicznego, skupiłem się jedynie na wymiarze fałszywości, gdzie dezinformacja to informacja weryfikowalnie fałszywa.

Tabela 1. *Klasyfikacja zaburzeń informacji Wardle'a *

	Disinformation	Misinformation	Mal-information
Fałszywość	Fałsz	Fałsz	Prawda
Propagacja w celu wyrządzenia szkody	Tak	Nie	Tak

* W języku polskim nie występują określenia różnicujące kategorie zaburzeń informacji.

Ale czym właściwie jest podatność na dezinformację? Pomimo swojej wszechobecności od czasów antycznych (Kaminska, 2017), dezinformacja i podatność na nią zaczęły przykuwać uwagę środowisk akademickich dopiero po roku 2016 (Gwiaździński et al., 2023). To właśnie wtedy odbyły się wybory prezydenckie w Stanach Zjednoczonych, a poprzedzająca je kampania wyborcza obfitowała w treści mylące i fałszywe (Guess et al., 2018), które rozprzestrzeniały się z niespotykaną wcześniej prędkością za pośrednictwem mediów społecznościowych. Za sprawą tych wydarzeń środowiska akademickie zaczęły poświęcać większą uwagę problematyce dezinformacji (Aird et al., 2018). W pierwszych próbach badania dezinformacji poziom podatności oceniano na podstawie trafności, z jaką badane jednostki rozróżniały informacje jako prawdziwe lub fałszywe (Swire et al., 2017; Aird et al., 2018). Takie zoperacjonalizowanie zjawiska, pomimo że trafne, z pewnością nie uwzględniało natury problemu w sposób holistyczny.

Na podstawie badań nad przepływem informacji w mediach społecznościowych wyciągnięto wnioski, że dezinformacja rozprzestrzenia się szybciej i szerzej (w ramach sieci społecznościowej) niż prawdziwe informacje (Vosoughi et al., 2018). Za sprawą tych badań zaczęto postrzegać dezinformację analogicznie do modeli epidemiologicznych (Kucharski, 2016), gdzie istotne są kontakt z patogenem, zarażenie siebie i zarażanie innych. W tym kontekście, to właśnie przekazywanie dezinformacji (zarażanie innych) jest kluczowym aspektem podatności na dezinformację (Scales et al., 2021).

W badaniach wchodzących w skład niniejszej rozprawy doktorskiej podatność na dezinformację zdefiniowałem w dwojaki sposób. Z jednej strony jako wyznacznik zarażenia siebie przyjąłem, jak jednostka ocenia prawdziwość przedstawianych jej nagłówków informacji. Jako że internauta, za sprawą polubień i dzielenia się treściami wchodzi w interakcję z informacjami napotykanymi w mediach społecznościowych, wyznacznikiem potencjalnego zarażania innych była kombinacja chęci polubienia i podzielenia się prezentowanymi treściami (zaangażowanie behawioralne). Dzięki uwzględnieniu zarówno aspektu poznawczego (ocena prawdziwości) i behawioralnego (chęć polubienia lub podzielenia się) podatności na dezinformację, udało mi się zbadać subtelne różnice pomiędzy tymi dwoma wymiarami.

Cel rozprawy doktorskiej

Celem niniejszej pracy doktorskiej było zbadanie wybranych różnic indywidualnych w zakresie procesów poznawczych oraz cech osobowości, które

mogą wpływać na odporność lub podatność na dezinformację. Od strony samej informacji, zbadałem jakie właściwości informacji – takie jak sposób jej prezentacji, populistyczna narracja czy użyteczność poznawcza, czyli potwierdzenie lub zaprzeczenie przekonań odbiorcy (Sharot and Sunstein, 2020) – zwiększają lub zmniejszają podatność na informację. Ponadto, za pomocą nowatorskiego podejścia do badań internetowych sprawdziłem, czy występują różnice w podatności na dezinformację pomiędzy osobami poddanymi farmakoterapii wpływającej na układ serotoninowy, a osobami, które nie przyjmowały leków. Badania te stanowią pionierski wstęp do eksploracji neurochemicznych korelatów podatności na dezinformację.

Do głównych celów badawczych niniejszej rozprawy doktorskiej należały:

- Konstrukcja i weryfikacja psychometrycznego narzędzia diagnostycznego pozwalającego na wielowymiarową ocenę indywidualnej podatności na dezinformację.

- Sprawdzenie, które z właściwości informacji wpływają na ocenę prawdziwości oraz behawioralne zaangażowanie w informacje.

- Zbadanie mechanizmów poznawczych determinujących podatność na dezinformację, takich jak: wrażliwość na pozytywne i negatywne informacje zwrotne, tendencyjność w interpretacji niejednoznacznych bodźców oraz asymetria w aktualizowaniu przekonań.

- Określenie cech psychologicznych zaangażowanych w podatność na dezinformację za pomocą metod kwestionariuszowych oceniających wymiary

osobowości na podstawie Pięcioczynnikowego Modelu Osobowości, lękliwości, narcyzmu i optymizmu.

- Zbadanie różnic w podatności na dezinformację między osobami przyjmującymi lek przeciwdepresyjny będący inhibitorem wychwytu zwrotnego serotoniny (sertralinę), a grupą uczestników nie przyjmujących żadnych leków o działaniu na ośrodkowy układ nerwowy.

Zaproponowane interdyscyplinarne badania, poprzez zastosowanie pionierskiej kombinacji metod eksperymentalnych, wyrafinowanych testów psychometrycznych oraz nowatorskiego narzędzia diagnozującego podatność na dezinformację, stworzyły wyjątkową możliwość przeprowadzenia eksperymentów z pogranicza psychologii, nauk poznawczych i medycyny. Analiza omówionych aspektów przetwarzania informacji przyczyniła się do głębszego poznania etiologii podatności na dezinformację i procesów poznawczych zaangażowanych w ten fenomen oraz, być może, w przyszłości umożliwi zaproponowanie potencjalnych metod zwiększających odporność na dezinformację.

Metodyka badań internetowych

Wszystkie badania wchodzące w skład rozprawy doktorskiej zostały przeprowadzone przy użyciu wyspecjalizowanych platform do badań za pośrednictwem Internetu (*online*). W dziedzinie nauk społecznych badania internetowe od wielu lat cieszą się popularnością ze względu na potencjalnie niskie koszty przeprowadzenia, szybki czas pozyskania danych i jednocześnie dostęp do

dużej, randomizowanej i reprezentatywnej próby badawczej (Taherdoost, 2016). Metody online zyskują zainteresowanie ostatnimi czasy również w naukach medycznych, szczególnie epidemiologicznych (Safdar et al., 2016).

Powyższa metodologia została wybrana z uwagi na podobieństwo do naturalnego środowiska badanej tematyki. Wszakże to właśnie Internet jest środowiskiem, w którym dezinformacja ma najłatwiejsze i najwygodniejsze warunki do propagacji. Znane są przypadki dezinformacji w mediach tradycyjnych, takich jak telewizja, radio czy prasa, jednakże nieprecyzyjna regulacja prawna Internetu, a także nieprzestrzeganie etyki dziennikarskiej w portalach pseudoinformacyjnych sprawiają, że to właśnie internetowe media społecznościowe można uznać za *niszę infodemiologiczną,* czyli środowisko sprzyjające rozprzestrzeniania się dezinformacji.

Metody kwestionariuszowe są najpowszechniejszym sposobem przeprowadzania badań online na szeroką skalę. Pomimo, że poprzez ich samoopisową nautrę, są one podatne na bardziej lub mniej świadomą konfabulację (Walzenbach, 2019), to kwestionariusze zastosowane w niniejszej pracy charakteryzują się najwyższymi właściwościami psychometrycznymi, takimi jak rzetelność i trafność, które zostały zweryfikowane na podstawie badań walidacyjnych. Opisy i odnośniki do badań walidacyjnych poszczególnych kwestionariuszy znajdują się w załączonych publikacjach.

Platformą, za pomocą której zbierałem dane pochodzące z metod kwestionariuszowych była platforma *Qualtrics XM*. Poza kwestionariuszami, dzięki zaawansowanym opcjom *Qualtrics XM* możliwe było zaimplementowanie niektórych

testów poznawczych, takich jak test interpretacji bodźca niejednoznacznego (Schick et al., 2013) czy test aktualizacji przekonań (Sharot et al., 2011).

W badaniach zastosowałem również oprogramowanie *Inquisit Web* firmy *Millisecond*, które umożliwia zaprogramowanie i przeprowadzenie wyrafinowanych testów poznawczych zdalnie przez Internet. Oprogramowanie to zyskało dużą popularność wśród badaczy procesów poznawczych i behawioralnych u ludzi (Millisecond Software, 2024). W badaniach wchodzących w skład niniejszej rozprawy doktorskiej, uczestnicy zostali poproszeni o pobranie aplikacji i wykonanie translacyjnego testu probabilistycznego przeuczania (Cools et al., 2002), który posłużył do oceny wrażliwości na wzmocnienia (Noworyta and Rygula, 2021; Zou et al., 2022).

Kluczowym elementem badań jest odpowiedni dobór próby. W kontekście badań internetowych jednym ze sposobów jest rekrutacja we własnym zakresie, polegająca na zamieszczeniu ogłoszenia o naborze na stronach i forach internetowych. Jest to sposób stosunkowo żmudny, a pozyskana próba budzi wiele zastrzeżeń ze względu na niską reprezentatywność i wątpliwą randomizację. Z tego powodu, w niniejszych badaniach skorzystałem z usług zewnętrznej firmy *Prolific Academic*, specjalizującej się w rekrutacji uczestników do badań online. Warto podkreślić, że platforma ta należy do licznej grupy serwisów o podobnym profilu usługowym. Jednakże w badaniach dotyczących jakości rekrutowanych prób badawczych, platforma *Prolific Academic* wykazała się najbardziej rzetelnymi odpowiedziami i wysokim współczynnikiem prawdomówności (Peer et al., 2022). Omawiana platforma

oferuje również prosty system kryteriów włączenia – potencjalny uczestnik badań podczas rejestracji wypełnia szczegółowy kwestionariusz osobowy, który, oprócz podstawowych danych takich jak płeć, wiek czy miejsce zamieszkania, zawiera liczne pytania szczegółowe, na przykład dotyczące historii chorób i przyjmowanych leków. To ostatnie umożliwiło przeprowadzenie badań opisanych w trzeciej publikacji wchodzącej w skład rozprawy.

Przeprowadzone badania

W niniejszej pracy doktorskiej skupiłem się na zbadaniu podstawowych mechanizmów regulujących podatność na dezinformację. Z uwagi na wyjątkowe okoliczności we współczesnych dziejach ludzkości, jakimi były pandemia Covid-19 oraz wszechobecna dezinformacja na temat tej choroby i sposobów jej zwalczania (głównie szczepień), przedmiotem badanej dezinformacji była właśnie pandemia. We współpracy z zespołem z Uniwersytetu w Oslo opracowałem skalę podatności na dezinformację (opisaną w pierwszej i drugiej publikacji), składającą się z nagłówków informacji stylizowanych na posty platformy *Facebook.* Połowa informacji zawierała informacje fałszywe, a połowa informacje prawdziwe. Ich prawdziwość była zweryfikowana na podstawie raportów Światowej Organizacji Zdrowia oraz stanowisk zespołu ds. Covid-19 przy prezesie Polskiej Akademii Nauk.

W pierwszym badaniu, opisanym w pracy pt.: „*Are we willing to share what we believe is true? Factors influencing susceptibility to fake news.*" autorstwa *Piksa M., Noworyta K., Gundersen A., Kunst J., Morzy M., Piasecki J., Rygula R.* opublikowanej na

łamach czasopisma *Frontiers in Psychiatry (2023)*, analizowałem jak właściwości informacji wpływają na ocenę prawdziwości i zaangażowanie behawioralne (chęć podzielenia się lub polubienia) prezentowanego nagłówka informacji. Pierwszym badanym czynnikiem była weryfikowalna prawdziwość, drugim użyteczność poznawcza, czyli spójność informacji z przekonaniami odbiorcy (Sharot and Sunstein, 2020), a trzecim był styl prezentacji – populistyczny lub rzetelny. Postawiłem hipotezę, że podatność na informację, rozumiana jako ocena prawdziwości lub chęć podzielenia się nią, różnić się będzie wobec nagłówków charakteryzujących się różną konfiguracją badanych czynników. We wcześniejszych badaniach wielokrotnie wykazywano, że w przypadku informacji politycznych, informacje wspierające poglądy respondentów były oceniane jako bardziej prawdziwe niż informacje spójne z innymi poglądami politycznymi (Pennycook and Rand, 2021). W badaniu przeprowadzonym na rzecz tej rozprawy, sprawdziłem czy wspomniany efekt dotyczyć będzie też poglądów na temat pandemii Covid-19. Okazało się, że przy ocenie prawdziwości uczestnicy badania kierowali się w głównej mierze weryfikowalną prawdziwością informacji. Co ciekawe, w przypadku behawioralnego zaangażowania (chęci podzielenia się) spójność z przekonaniami odbiorców informacji była bardziej istotnym czynnikiem niż obiektywna prawdziwość czy styl prezentacji. Na tej podstawie wyciągnąłem wniosek, że spójność informacji z poglądami – nie tylko politycznymi – jest kluczowym czynnikiem podatności na (dez)informację.

Drugie badanie szczegółowo opisane w pracy pt.: „*Cognitive Processes and Personality Traits Underlying Four Phenotypes of Susceptibility to (Mis)Information.*"

autorstwa *Piksa M., Noworyta K., Piasecki J., Gwiazdzinski P., Gundersen A.B., Kunst J., Rygula R.* opublikowanej w *Frontiers in Psychiatry (2022)*, zostało przeprowadzone w celu identyfikacji różnic indywidualnych dotyczących procesów poznawczych i cech osobowości, które zaangażowane są w podatność na dezinformację. W pracy tej w pierwszej kolejności wykazałem, że podatność na dezinformację jest niezależna od podatności na informacje prawdziwe. Oznacza to, że jedna osoba może być podatna zarówno na informacje prawdziwe i fałszywe, a inna osoba może być niepodatna ani na prawdziwe, ani na fałszywe. Istnieją jeszcze dwie inne grupy – osoby podatne tylko na jeden typ (prawdziwy lub fałszywy) informacji. W prezentowanej publikacji takie różne konfiguracje podatności określiłem jako cztery fenotypy podatności na (dez)informację. Wątpiący (ang. *doubters*) to osoby niepodatne na żaden typ informacji. Ich przeciwieństwem są konsumenci (ang. *consumers*), wrażliwi zarówno na informacje prawdziwe, jak i fałszywe. Wiedzący (ang. *knowers*) to fenotyp wysoko ceniący informacje prawdziwe i ignorujący informacje fałszywe. Ich przeciwieństwo stanowią naiwniacy (ang. *duffers*), podatni głównie na *fake newsy*. Co ciekawe i najbardziej kluczowe, badane fenotypy różniły się między sobą pod względem różnych procesów poznawczych, na przykład wrażliwości na wzmocnienie czy tendencyjności poznawczej oraz cech osobowości takich jak lękliwość, optymizm czy narcyzm. Wnioski płynące z tych badań wskazują, że niektóre procesy poznawcze oraz cechy osobowości istotnie modulują podatność na dezinformację.

Wskazane powyżej mechanizmy psychopoznawcze i ich zaburzenia często towarzyszą chorobom afektywnym, szczególnie depresji (Joormann and Siemer, 2011;

Joormann and Quinn, 2014). Na tej podstawie postawiłem hipotezę, że podatność na (dez)informację i zaburzenia afektywne mogą mieć wspólny mechanizm neurochemiczny oparty na przekaźnictwie serotoninergicznym. Dlatego też w trzecim badaniu opisanym w pracy pt.: „*Research Report: A Link between Sertraline Treatment and Susceptibility to (Mis)information."* autorstwa *Piksa M., Noworyta K., Piasecki J., Gundersen A., Kunst J., Morzy M., Rygula R.* opublikowanej w czasopiśmie *ACS Chemical Neuroscience (2024)* sprawdziłem czy podatność na (dez)informację różni się między osobi przyjmującymi sertralinę (lek przeciwdepresyjny będący najczęściej przyjmowaną substancją z grupy selektywnych inhibitorów wychwytu zwrotnego serotoniny w populacji użytkowników platformy *Prolific Academic*) a grupą kontrolną nie przyjmującą żadnych leków psychotropowych. Wykazałem, że osoby przyjmujące sertralinę w dawce 150 mg/dzień przez okres dłuższy niż 8 tygodni, były bardziej skłonne do dzielenia się otrzymanymi informacjami, niż osoby nie zażywające żadnych leków psychotropowych. Nie wykryłem jednak różnic pomiędzy podatnością na informacje prawdziwe, a podatnością na informacje fałszywe. Postawiłem wniosek, że sertralina wykazuje niespecyficzny wpływ na podatność na informację, co przypuszczalnie wynika z jej efektów przeciwlękowych i prospołecznych. Aktywne korzystanie z sieci społecznościowych może wywoływać lęk społeczny (Keles et al., 2020), a sertralina posiadająca właściwości anksjolityczne (Allgulander et al., 2004) wywoływała zachowanie ukierunkowane na interakcje społeczne – dzielenie się informacją.

Podatność na dezinformację a psychiatria

Choć mogłoby się wydawać, że omawiana w tej pracy doktorskiej tematyka przynależy do domeny nauk społecznych, głównie psychologii, to warto rozważyć kontrowersyjną kwestię symptomatologii i psychopatologii jaką podatność na dezinformację zdaje się w sobie zawierać. Biorąc pod uwagę daleko idące zdrowotne i społeczne konsekwencje podatności na dezinformację, np. ryzyko osłabienia odporności populacyjnej przez zmniejszoną chęć szczepień, czy też szturm na Kapitol wywołany fałszywymi oskarżeniami D. Trumpa o sfałszowaniu wyborów w 2020 roku, zasadnym wydaje się postawienie pytania, czy podatność na dezinformację spełnia poniższe kryteria zaburzenia psychicznego? Zgodnie z Kryteriami Diagnostycznymi Zaburzeń Psychicznych, wydanie piąte (DSM-5)(American Psychiatric Association, 2013) *zaburzenie psychiczne jest zespołem objawów, który charakteryzuje się znaczącym klinicznie zakłóceniem indywidualnego poznawania, regulacji emocji lub zachowania, które odzwierciedlają psychologiczną, biologiczną albo rozwojową dysfunkcję, leżącą u podstaw funkcjonowania psychicznego. Zaburzenia psychiczne są zwykle związane z cierpieniem lub niepełnosprawnością w realizacji zadań społecznych, zawodowych bądź innych, równie ważnych. […] Zachowanie społeczne dewiacyjne (przykładowo, polityczne, religijne czy społeczne) i konflikty, które rodzą się między jednostką a społeczeństwem, nie są zaburzeniami psychicznymi, chyba że dewiacja wynika z dysfunkcji danej jednostki, jak to przedstawiono powyżej.*

Podane przykłady skutków podatności na dezinformację mogą zostać uznane za dewiacje. W świetle przytoczonej definicji, dewiacje, choć same w sobie nie są zaburzeniem, to mogą być tak zaklasyfikowane pod warunkiem, że są wynikiem *dysfunkcji poznania, regulacji emocji lub zachowania*. Biorąc pod uwagę dotychczasowe doniesienia naukowe, a także wyniki zaprezentowane w niniejszej rozprawie doktorskiej, należy zwrócić uwagę, że podatność na dezinformację koreluje z zakłóceniami w przetwarzaniu informacji, sztywnością poznawczą a także stanami emocjonalnymi, np. lękliwością, i tym samym spełnia definicyjne wymogi zaburzenia psychicznego.

Badając tę hipotezę można również rozważyć, czy podatność na dezinformację mogłaby być współczesnym przejawem symptomu któregoś z już istniejących zaburzeń. Biorąc pod uwagę istotną funkcję indywidualnych przekonań w kontekście podatności na dezinformację, należy dokładniej przyjrzeć się zaburzeniom osobowości, szczególnie paranoicznym. Zgodnie z kryteriami diagnostycznymi, charakterystyczne objawy tego zaburzenia to brak zaufania, podejrzliwość, interpretowanie motywów działania innych osób jako wrogich, pomimo braku wystarczająco wiarygodnych dowodów. W przypadku dezinformacji, częstym i powtarzającym się motywem jest kwestia szkodliwości szczepień, kontrola obywateli, oszustwa polityków i ogólnie pojęte teorie spiskowe.

Postawiona hipoteza, pomimo swej atrakcyjności, przy obecnym stanie wiedzy nie jest możliwa do zweryfikowania. Mimo wszystko uważam jednak, że zgromadzone wyniki badań oraz wyciągnięte na ich podstawie wnioski stanowią

solidną podstawę do dalszej eksploracji tego zagadnienia w kontekście psychiatrycznym.

Kierunki dalszych badań

Mimo że już w starożytnym Rzymie pojawiały się pierwsze wzmianki o dezinformacji (Kaminska, 2017), to dopiero po roku 2016 środowiska naukowe wyraźnie zwiększyły swoje zainteresowanie tym zagadnieniem (Oyserman and Dawson, 2020). W momencie rozpoczęcia badań leżących u podstaw tej rozprawy nie istniała jednolita, wystandaryzowana metodologia badania podatności na dezinformację. Badania politologów skupiały się na analizie wpływu *fake newsów* na poparcie danych opcji politycznych (Swire et al., 2017). Z kolei psychologowie skupiali się na heurystykach stojących za bezrefleksyjną wiarą w napotykane treści (Pennycook and Rand, 2021). Znane były tylko nieliczne doniesienia literaturowe wykraczające poza powyższe domeny. Jak wykazaliśmy w pracy przeglądowej (Gwiaździński et al., 2023), nie wchodzącej w skład tej rozprawy, jeszcze mniej publikacji donosi o skutecznych metodach przeciwdziałania podatności na dezinformację. Moje badania, łącząc nauki społeczne, biologiczne i medyczne, stanowią pionierską próbę podejścia do problemu w sposób interdyscyplinarny. Choć na podstawie uzyskanych wyników trudno o wskazanie konkretnych strategii przeciwdziałających podatności na dezinformację, to z pewnością mogą one pomóc w zrozumieniu podstaw tego problemu.

Po pierwsze, w przyszłych badaniach należy uwzględnić różnorodną tematykę dezinformacji. Pierwsze badania nad *fake newsami* skupiały się na tematyce politycznej, szczególnie amerykańskiego konfliktu politycznego pomiędzy demokratami i republikanami. W przedstawionych badaniach (dez)informacja dotyczyła pandemii Covid-19, a więc kwestii zachowań prozdrowotnych, prewencyjnych i leczenia. Z kolei w ostatnich latach dezinformacja wykorzystywana jest w kontekście wojny Rosyjsko-Ukraińskiej. Pozostaje niewiadomym, czy do podobnych wniosków można byłoby dojść, gdyby to właśnie wojna lub dowolna inna kwestia, była badaną tematyką.

Po drugie, obszar różnic indywidualnych zdaje się być niedostatecznie przebadany. Jak wykazałem w drugiej publikacji, cechy osobowości czy różnice w mechanizmach poznawczych w sposób istotny modulują podatność na dezinformację. To właśnie różnice indywidualne sprawiają, że jedna osoba zostaje wierna antyszczepionkowym poglądom a inna kieruje się aktualnymi osiągnięciami nauki. W kontekście podatności na dezinformację wartymi uwagi aspektami osobowości, a niezbadanymi w tej rozprawie, wydają się być, między innymi, ufność (do autorytetów), paranoiczność czy style przywiązania w relacjach.

Po trzecie, zaprezentowane badania dotyczące osób przyjmujących sertralinę stanowią jedynie kierunkowskaz do dalszej eksploracji mechanizmów przetwarzania informacji. Jak wielokrotnie wykazano, serotonina odgrywa kluczową rolę w przetwarzaniu informacji (Schmitt et al., 2006), zapamiętywaniu (Buhot et al., 2000) czy regulacji emocji (Meneses and Liy-Salmeron, 2012). Z jednej strony należałoby

dogłębniej zbadać rolę serotoniny w podatności na dezinformację, jak również ocenić

funkcję innych neuroprzekaźników, na przykład dopaminy.

Wreszcie, po pełniejszym zrozumieniu istoty mechanizmów podatności lub

odporności na dezinformację należy skoncentrować się na opracowaniu skutecznych

metod zapobiegania i wzmacniania odporności na kłamliwe, zmanipulowane treści.

„Jeżeli nie mamy faktów, nie możemy mieć i prawdy. Bez prawdy, nie ma zaufania. Bez tych

trzech nie mamy wspólnej rzeczywistości. Nie rozwiążemy żadnego problemu. Nie istnieje

demokracja bez spójności faktów" – Maria Ressa, laureatka Pokojowej Nagrody Nobla,

tłumaczenie własne.

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Artykuły wchodzące w skład rozprawy doktorskiej

Are we willing to share what we believe is true? Factors influencing susceptibility to fake news

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Background: The contemporary media landscape is saturated with the ubiquitous presence of misinformation. One can point to several factors that amplify the spread and dissemination of false information, such as blurring the line between expert and layman's opinions, economic incentives promoting the publication of sensational information, the zero cost of sharing false information, and many more. In this study, we investigate some of the mechanisms of fake news dissemination that have eluded scientific scrutiny: the evaluation of veracity and behavioral engagement with information in light of its factual truthfulness (either true or false), cognitive utility (either enforcing or questioning participants' beliefs), and presentation style (either sober or populistic).

Results: Two main results emerge from our experiment. We find that the evaluation of veracity is mostly related to the objective truthfulness of a news item. However, the probability of engagement is more related to the congruence of the information with the participants' preconceived beliefs than to objective truthfulness or information presentation style.

Conclusion: We conclude a common notion that the spread of fake news can be limited by fact-checking and educating people might not be entirely true, as people will share fake information as long as it reduces the entropy of their mental models of the world. We also find support for the Trojan Horse hypothesis of fake news dissemination.

Introduction

As we go about our daily lives, we are constantly exposed to new information, including news reports regarding the pandemic or Russia's invasion of Ukraine, politicians' statements about domestic policy, friends' descriptions of new restaurants, and celebrity gossip. However, how do we decide what is true and what is false? This question is more pertinent today than ever. Modern social media blurs the line between facts and opinions, which opens up the opportunity for misinformation.

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The ability and ease of sharing information on social media can amplify the effects of the malicious spread of fake news. Therefore, an important research challenge is to determine how people assess the veracity of the information they encounter and how those decisions affect their online behavior, e.g., by ignoring or sharing it. Understanding how people make decisions about such actions is important for many fields, ranging from politics and national security through finance to education and public health.

Apart from information's objective truthfulness, when assessing people's susceptibility to fake news, it is also crucial to consider the cognitive utility of the news, which can be defined as the ability of information to enhance or reduce people's sense of understanding the world around them (1). In 2010, Friston suggested that people strive to minimize the difference between the mental models that they use to comprehend and actual external reality to ensure that their sensory entropy remains low (2). This can be achieved either by seeking out information that strengthens the uncertain elements of the adopted mental models and/or by avoiding information that is suspected to weaken or disconfirm them. In other words, people tend to reduce the cognitive dissonance between the internal representation of reality and the actual external reality and tend to improve their sense of comprehension by actively selecting or avoiding the information on which they build their awareness (3).

There is also a range of contextual factors that may influence an individual's tendency to believe the news (4). These include presentation style elements that increase the affective load and references to a social consensus increasing the veracity of the news. Fake news is typically accompanied by a photograph that may or may not provide additional information about the content of the story, but it is often emotionally evocative and geared toward provoking shock, fear, or anger. Previous research has shown that presenting a photograph alongside a text description increases veracity ratings (5), and the emotional load increases belief in the news (6). Similarly, a reference to a source and the use of wording in the form of social consensus, e.g., "as many of us already know" or "as reported by multiple sources", can trick people into feeling an increased sense of truthfulness (7).

Apart from problems with the evaluation of information veracity, susceptibility to fake news can also be associated with engagement with the news, e.g., a willingness to share it with peers or in social media environments, through likes, shares, comments, etc. (8). Indeed, the desire to share information within one's social circle is deeply rooted in evolution (9). As gossiping serves to build trust networks in past generations, sharing, liking, and commenting on online information in social networks reinforces trust in digital communities (10). We believe that the evolutionary trait underlying the propensity to share online information is an important index of fake news susceptibility (11).

Based on this multifactorial and multidimensional framework, we investigated how three factors, truthfulness (true vs. false), cognitive utility (congruent vs. incongruent), and presentation style (populistic vs. sober) influence the susceptibility to COVID-19 (mis)information at the level of veracity judgment and behavioral engagement with the news. The choice of the news topic was dictated by the fact that, during the data collection, most people around the globe were heavily engaged with the COVID-19 pandemic.
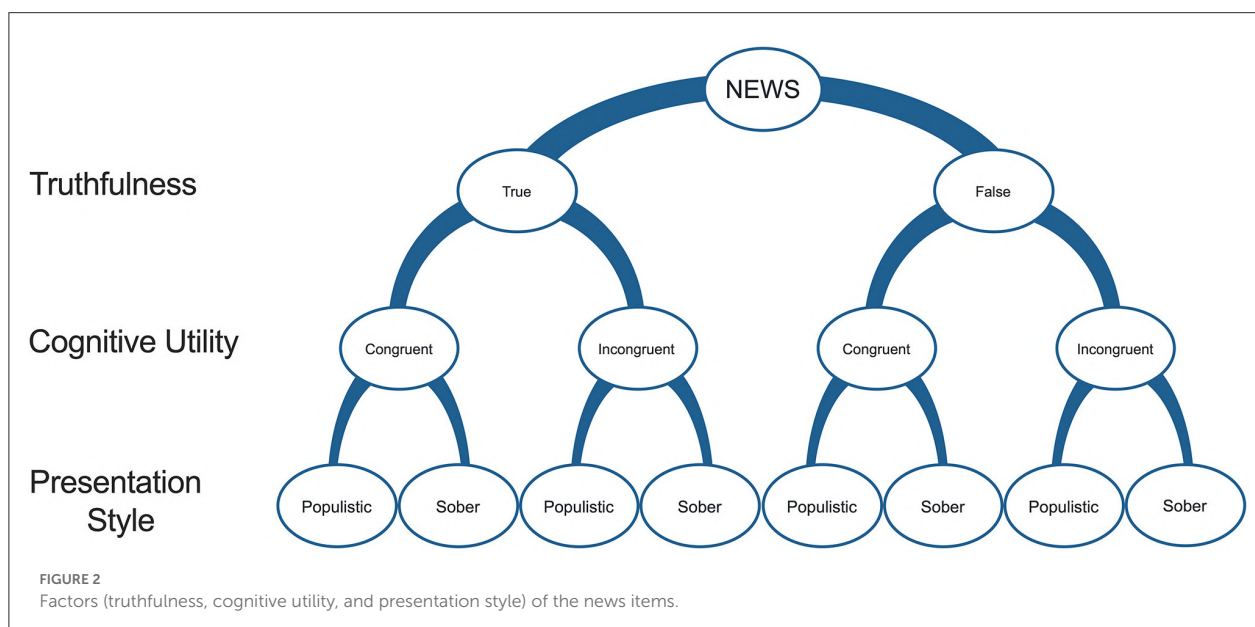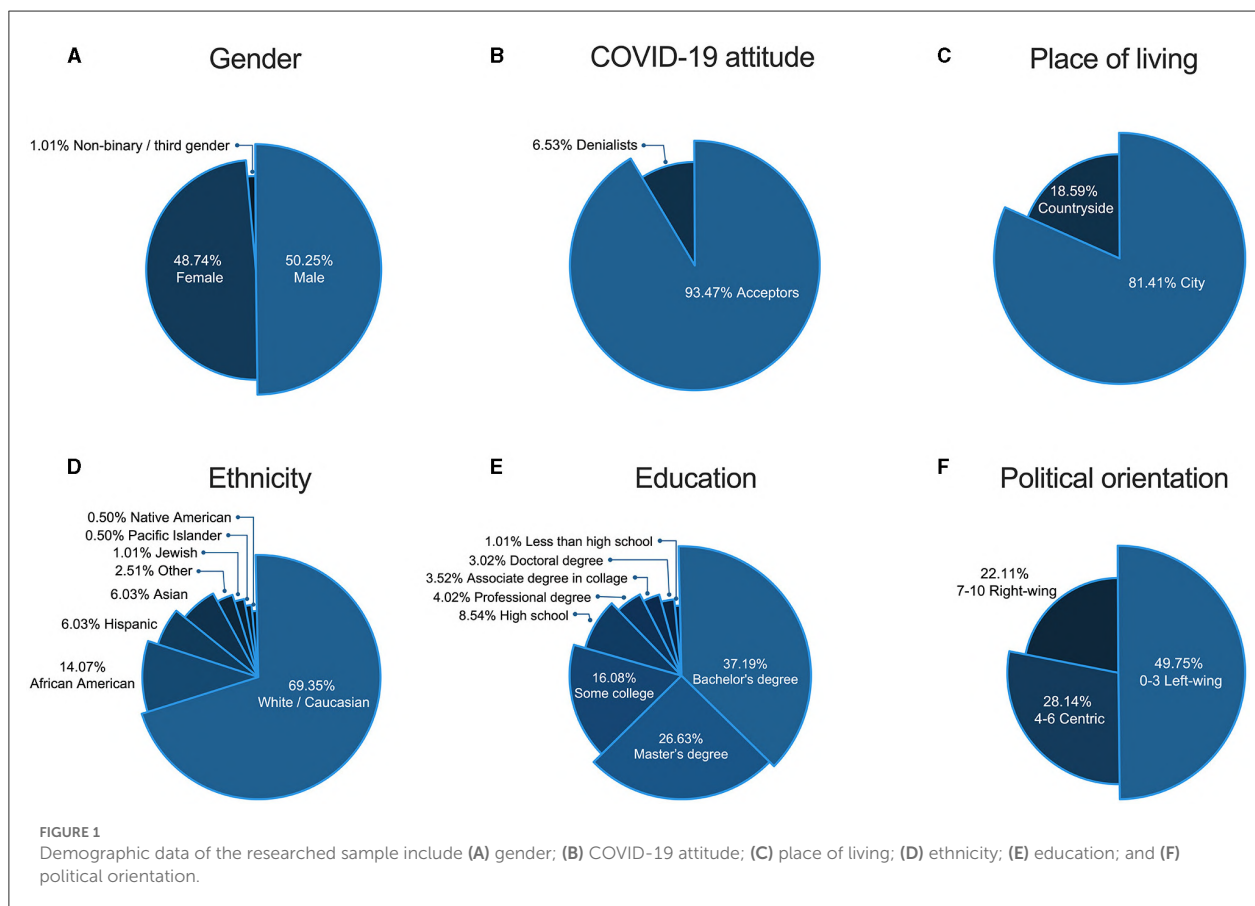
Materials and methods

Ethics statement

The study was conducted in accordance with all legal requirements regarding the conduct of scientific research in the Kingdom of Norway and the guidelines laid down in the Declaration of Helsinki. Consent was obtained from all subjects. The identical study design was approved by the Bioethics Committee of the Jagiellonian University in Krakow, Poland (1072.6120.66.2021).

Participants

The sample of 201 adult Americans was recruited by Prolific Academic. To receive reliable answers, we recruited only people who had previously participated in a minimum of 100 studies and a maximum of 500 studies, with an acceptance rate of $\geq$95% for the submitted surveys. During the survey, the participants had to pass two attentional checks (e.g., *It is important that you pay attention to this study. Please tick "Somewhat agree"*), and all participants answered all checks correctly. Two participants who did not declare their attitude toward the COVID-19 pandemic were excluded from further analysis, as this attitude was crucial for determining the cognitive utility (congruency with one's views) of each news item (see subsection "News items", section "Materials and methods"). The final sample ($N = 199$, $M_{age} = 36.32$, SD $= 11.11$) included 186 participants who declared that the pandemic is, at least to some degree, a real threat (further called Acceptors) and 13 participants who declared that the pandemic is, at least to some degree, a hoax (further called Denialists). A summary of other demographic data is presented in Figure 1.

News items

To test which features of the news contribute the most to the susceptibility to (mis)information, we designed 80 news items that could be categorized into eight types on the basis of three factors' modalities: truthfulness (true vs. fake), cognitive utility (congruent vs. incongruent with the personal attitude toward the COVID-19 pandemic), and presentation style (populistic vs. sober; described later in this subsection). The eight possible types of items were (1) fake, congruent, and populistic; (2) fake, congruent, and sober; (3) fake, incongruent, and populistic; (4) fake, incongruent, and sober; (5) true, congruent, and populistic; (6) true, congruent, and sober; (7) true, incongruent, and populistic; and (8) true, incongruent, and sober (Figure 2). All of the news items were prepared to mimic a Facebook-like format, i.e., they consisted of a news headline, a picture, a subtext line, and the source of the information. The topic of the news was connected to the COVID-19 pandemic because most people around the globe were absorbed in it at the time of data collection, making it more ecologically valid. Half of the items presented objective truths based on information from the official WHO guidelines (12). The other half presented false information, which was invented and verified

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FIGURE 1
Demographic data of the researched sample include **(A)** gender; **(B)** COVID-19 attitude; **(C)** place of living; **(D)** ethnicity; **(E)** education; and **(F)** political orientation.

FIGURE 2
Factors (truthfulness, cognitive utility, and presentation style) of the news items.

as false by the research team. Second, to investigate the effects of information utility on its valence, we designed the items to reflect the polarization in beliefs about the COVID-19 pandemic. One-half of the news was congruent with the view that the COVID-19 pandemic is real and threatening (i.e., in line with the attitude of acceptors), while the other half was created to align with the view that the pandemic is a hoax (i.e., in line with the attitude of denialists). We, thus, assumed that the news that aligns and fits

with the view that the COVID-19 pandemic is real and threatening will be congruent with the attitude of acceptors (positive cognitive utility) and, at the same time, incongruent with the attitude of denialists (negative cognitive utility), and vice versa—the news claiming that COVID-19 is a hoax will be incongruent with the attitude of acceptors (negative cognitive utility) and, at the same time, congruent with the attitude of denialists (positive cognitive utility).

As mentioned above, apart from actual truthfulness and cognitive utility, a range of contextual factors (e.g., presentation style) can influence the tendency to believe and share the news (4–7). Thus, half of the news items were presented with elements that increased affective load (e.g., a sensational headline that dramatized more than the text below, accompanied by a bright, colorful, and high contrast, sensational picture), social consensus (text with references to common agreement), and references to alternative (non-mainstream) sources of information (populistic presentation). The other half was presented as sober facts, countering or lacking the abovementioned features (i.e., they had a sober presentation style). All the news items are available in an online repository (13).

The susceptibility to (mis)information was defined on two levels. The participants were asked to evaluate each item in terms of its veracity (*Do you think the news above is true?*), on a 6-point Likert scale, where 1 was *definitely false* and 6 was *definitely true*, and the probability of engagement with it (willingness to like—*On social media, I would give a "like" to this news*, and willingness to share—*I would share this news on my social media profile*), on a 6-point Likert scale, where 1 was *totally disagree* and 6 was *totally agree*. For the internal consistency measures, please see Supplementary material.

Statistical analysis

The data were analyzed using SPSS (version 27.0, SPSS INC., Chicago, IL, USA). Three-way repeated measures analysis of variance (ANOVA) with Sidak *post-hoc* adjustment was performed to determine the main effects of and the interactions among the factor's truthfulness (true vs. false), cognitive utility (congruent vs. incongruent), and presentation style (populistic vs. sober) on the dependent variables: veracity rating and engagement with the news.

Distribution of the data within groups was tested using the Kolmogorov–Smirnov test, and homogeneity of variances was tested using Levene's test. The sphericity of the ANOVA was verified using Mauchly's test. To determine the most influential factor out of the three investigated ones affecting veracity judgment, the scores of veracity for one modality were initially subtracted from the scores of the counter-modality in respective categories: $\Delta_{veracity}$ truthfulness $= |true_{veracity} - false_{veracity}|$; $\Delta_{veracity}$ cognitive utility $= |congruent_{veracity} - incongruent_{veracity}|$; and $\Delta_{veracity}$ presentation style $= |populistic_{veracity} - sober_{veracity}|$. These differences were, then, compared using repeated measures of one-way ANOVA followed by *post-hoc* tests with Sidak adjustment. Analogous operations were performed for engagement scores.

Procedure

The study was conducted between 14 April 2021 and 16 April 2021. Eligible participants were recruited for the study via Prolific Academic, where they found the essential information and instructions. Following informed consent, they were redirected to Qualtrics.com, where they completed the survey.

The survey consisted of 80 news items, displayed in a random order, followed by claims on a 6-point Likert scale, where 1 represented *totally disagree* and 6 represented *totally agree*:

1) *On social media, I would give a "like" to this news.*
2) *I would share this news on my social media profile.*

The news items were, then, presented again, but this time, the participants had to judge the news' veracity on a 6-point Likert scale, where 1 was *definitely false* and 6 was *definitely true*.
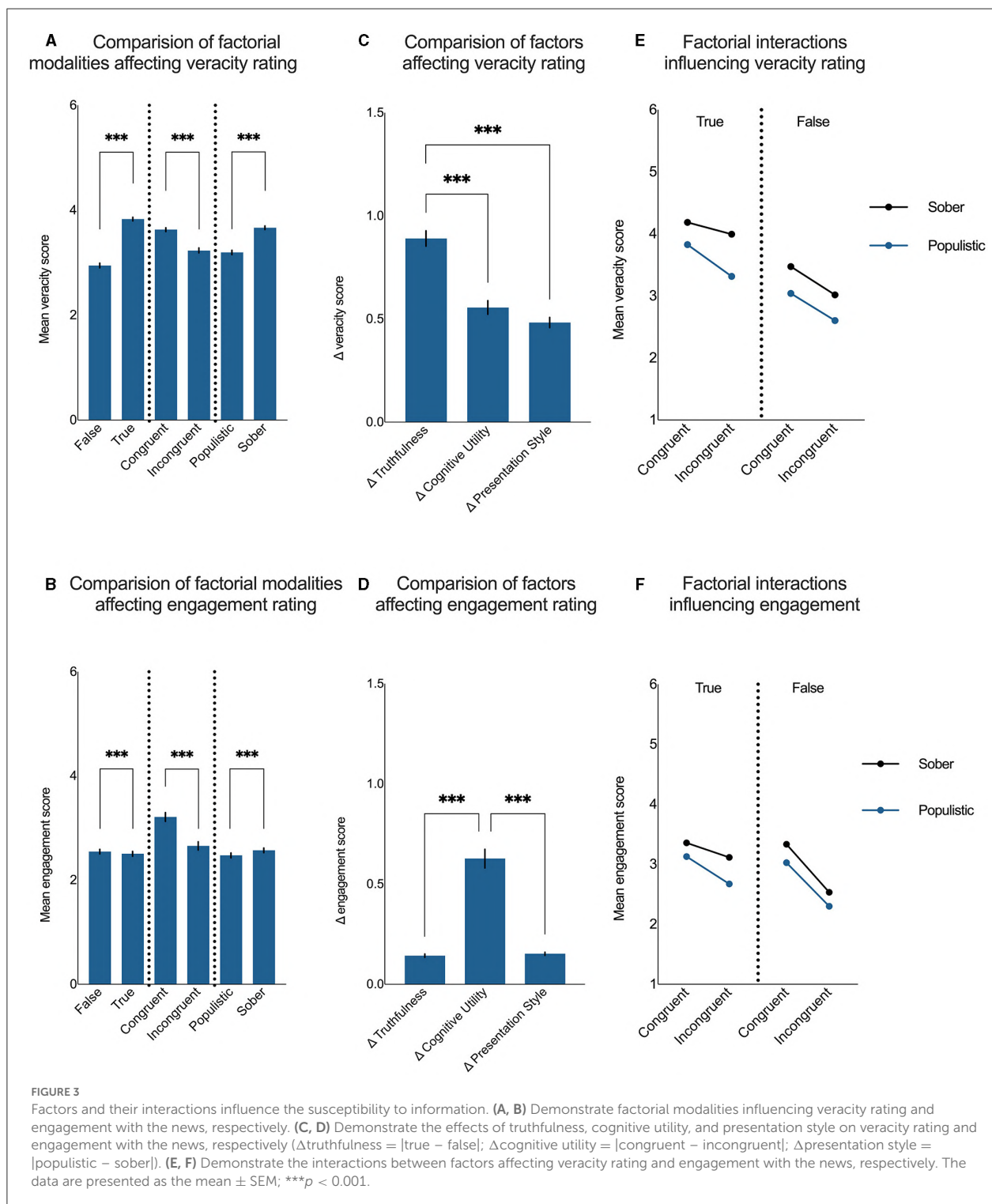
Participants rated the engagement and veracity in two separate series of news item presentations because prior veracity judgment might decrease their willingness to engage with the news (8).

The end of the survey consisted of a demographic questionnaire and a debrief regarding the news items. After completing the survey, the participants were compensated with 5.63 GBP.

Results and discussion

The results of our study revealed that the true news items were rated as significantly more true than those that were false [$F_{(0.81,161)} = 408.87$, $p < 0.001$, Figure 3A]. The same was observed for the news that was congruent with the rater's attitude compared with those that were incongruent [$F_{(0.82,163)} = 84.24$, $p < 0.001$, Figure 3A] and for those presented in a sober manner compared with those presented in a populistic style [$F_{(0.98,193)} = 314.72$, $p < 0.001$, Figure 3A]. Subsequent comparisons revealed that the veracity judgment was significantly ($p < 0.001$) more influenced by the actual truthfulness of the news than its cognitive utility or presentation style [$F_{(1.8,357)} = 49.49$, $p < 0.001$; Figure 3C].

While the abovementioned results seem intuitive, the behavioral engagement with the news turned out to be significantly higher for the fake news than that which was objectively true [$F_{(0.71,140)} = 64.10$, $p < 0.001$; Figure 3B]. In terms of cognitive utility and presentation style, similar to veracity ratings, the behavioral engagement with the news was significantly higher for the news items that were congruent with the participant's attitude than those that were incongruent [$F_{(0.90,178)} = 118.30$, $p < 0.001$, Figure 3B] and for those that were presented in a sober manner compared with the news items presented in a populistic manner [$F_{(0.87,172)} = 134.05$, $p < 0.001$, Figure 3B]. Engagement with the news was significantly ($p < 0.001$) more influenced by its cognitive utility than its truthfulness or the way it was presented [$F_{(1.1,216)} = 108.45$, $p < 0.001$; Figure 3D]. The observation that the actual truthfulness of the news is essential for the assessment of its veracity and not for the behavioral engagement with it suggests that, for grasping the complex nature of susceptibility to fake news, this phenomenon must be considered on at least two different levels: how people assess the veracity of given information and how

FIGURE 3
Factors and their interactions influence the susceptibility to information. **(A, B)** Demonstrate factorial modalities influencing veracity rating and engagement with the news, respectively. **(C, D)** Demonstrate the effects of truthfulness, cognitive utility, and presentation style on veracity rating and engagement with the news, respectively (Δtruthfulness = |true − false|; Δcognitive utility = |congruent − incongruent|; Δpresentation style = |populistic − sober|). **(E, F)** Demonstrate the interactions between factors affecting veracity rating and engagement with the news, respectively. The data are presented as the mean ± SEM; ***$p < 0.001$.

likely they are to share it with their peers. These results suggest that when assessing the veracity of the news, people tend to focus mostly on its truthfulness, whereas when engaging with the news, they prefer information that is congruent with their view rather than actually true. This observation might further explain why fake news spreads faster and further on social media than news that is true (14). An important remark suggests that the mentioned finding could be due to fake news' ability to evoke emotions such as surprise, fear, and disgust (14) that play a crucial role in the cognitive utility of the information (1).

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TABLE 1　*Post-hoc* tests for three-way ANOVA on factors influencing veracity judgment of news.

Šídák's multiple comparisons test	Mean diff.	t	Adjusted P-value
Congruent | True | Sober vs. Congruent | True | Populistic	0.36	10.28	<0.001
Congruent | True | Sober vs. Congruent | Fake | Sober	0.71	13.99	<0.001
Congruent | True | Sober vs. Congruent | Fake | Populistic	1.14	18.14	<0.001
Congruent | True | Sober vs. Incongruent | True | Sober	0.19	4.26	<0.001
Congruent | True | Sober vs. Incongruent | True | Populistic	0.87	14.74	<0.001
Congruent | True | Sober vs. Incongruent | Fake | Sober	1.17	19.13	<0.001
Congruent | True | Sober vs. Incongruent | Fake | Populistic	1.58	23.59	<0.001
Congruent | True | Populistic vs. Congruent | Fake | Sober	0.36	6.78	<0.001
Congruent | True | Populistic vs. Congruent | Fake | Populistic	0.79	13.86	<0.001
Congruent | True | Populistic vs. Incongruent | True | Sober	−0.17	3.57	0.012
Congruent | True | Populistic vs. Incongruent | True | Populistic	0.52	10.50	<0.001
Congruent | True | Populistic vs. Incongruent | Fake | Sober	0.81	14.76	<0.001
Congruent | True | Populistic vs. Incongruent | Fake | Populistic	1.23	21.60	<0.001
Congruent | Fake | Sober vs. Congruent | Fake | Populistic	0.43	12.29	<0.001
Congruent | Fake | Sober vs. Incongruent | True | Sober	−0.52	8.58	<0.001
Congruent | Fake | Sober vs. Incongruent | True | Populistic	0.16	2.37	0.408
Congruent | Fake | Sober vs. Incongruent | Fake | Sober	0.46	8.21	<0.001
Congruent | Fake | Sober vs. Incongruent | Fake | Populistic	0.87	14.18	<0.001
Congruent | Fake | Populistic vs. Incongruent | True | Sober	−0.96	13.11	<0.001
Congruent | Fake | Populistic vs. Incongruent | True | Populistic	−0.27	3.88	0.004
Congruent | Fake | Populistic vs. Incongruent | Fake | Sober	0.03	0.42	>0.999
Congruent | Fake | Populistic vs. Incongruent | Fake | Populistic	0.44	7.30	<0.001
Incongruent | True | Sober vs. Incongruent | True | Populistic	0.68	16.06	<0.001
Incongruent | True | Sober vs. Incongruent | Fake | Sober	0.98	20.80	<0.001
Incongruent | True | Sober vs. Incongruent | Fake | Populistic	1.40	24.48	<0.001
Incongruent | True | Populistic vs. Incongruent | Fake | Sober	0.30	7.01	<0.001
Incongruent | True | Populistic vs. Incongruent | Fake | Populistic	0.71	16.87	<0.001
Incongruent | Fake | Sober vs. Incongruent | Fake | Populistic	0.41	12.54	<0.001

DF = 199.

All three investigated factors (truthfulness, cognitive utility, and presentation style) significantly interacted in the process of veracity rating [$F_{(0.83,165)} = 38.88$, $p < 0.001$]. The news items that received the highest veracity scores were true, congruent with the participant's attitude, and presented in a sober manner (Figure 3E). Those news items that received the lowest veracity rating were false, incongruent with the participant's attitude, and presented in a populistic manner (Figure 3E).

In terms of engagement with the news, the most engaging items were congruent with the rater's attitude and presented in a sober manner [$F_{(0.82,163)} = 27.59$, $p < 0.001$]. For such items, we found very little evidence for actual truthfulness to influence the engagement scores ($p > 0.999$). At the same time, those items that were the least engaging were false, incongruent with the rater's attitude, and presented in a populistic way (Figure 3F). Interestingly, the news that was true and sober but incongruent

with the rater's attitude was less engaging than the news that was false and soberly presented but congruent ($p = 0.032$, Figure 3F). The results of all remaining *post-hoc* comparisons are presented in Table 1 (for veracity ratings) and Table 2 (for engagement ratings).

Our results revealed that for the active spreading of information, its consistency with preexisting beliefs is more important than its actual veracity, especially if the information is presented in a sober manner. This observation suggests that one of the most effective ways of spreading misinformation can be based on the Trojan Horse (15) idea. The information designed in this way would have two components: a disinformation carrier and disinformation on its own. The carrier comprises information that is consistent with the opinion of a part of society on one of the most polarizing topics, such as politics or COVID-19, which, through its compliance with the views of the recipients, would be widely shared, dragging with it the

TABLE 2 *Post-hoc* tests for three-way ANOVA on factors influencing engagement with news.

Šídák's multiple comparisons test	Mean diff.	t	Adjusted P-value
Congruent | True | Sober vs. Congruent | True | Populistic	0.23	6.64	<0.001
Congruent | True | Sober vs. Congruent | Fake | Sober	0.02	0.53	>0.999
Congruent | True | Sober vs. Congruent | Fake | Populistic	0.33	6.38	<0.001
Congruent | True | Sober vs. Incongruent | True | Sober	0.24	5.40	<0.001
Congruent | True | Sober vs. Incongruent | True | Populistic	0.69	11.69	<0.001
Congruent | True | Sober vs. Incongruent | Fake | Sober	0.82	12.09	<0.001
Congruent | True | Sober vs. Incongruent | Fake | Populistic	1.06	14.46	<0.001
Congruent | True | Populistic vs. Congruent | Fake | Sober	−0.20	3.70	0.008
Congruent | True | Populistic vs. Congruent | Fake | Populistic	0.11	2.22	0.540
Congruent | True | Populistic vs. Incongruent | True | Sober	0.01	0.31	>0.999
Congruent | True | Populistic vs. Incongruent | True | Populistic	0.46	10.08	<0.001
Congruent | True | Populistic vs. Incongruent | Fake | Sober	0.60	10.08	<0.001
Congruent | True | Populistic vs. Incongruent | Fake | Populistic	0.83	13.59	<0.001
Congruent | Fake | Sober vs. Congruent | Fake | Populistic	0.31	7.02	<0.001
Congruent | Fake | Sober vs. Incongruent | True | Sober	0.22	3.30	0.032
Congruent | Fake | Sober vs. Incongruent | True | Populistic	0.66	8.95	<0.001
Congruent | Fake | Sober vs. Incongruent | Fake | Sober	0.80	10.51	<0.001
Congruent | Fake | Sober vs. Incongruent | Fake | Populistic	1.04	13.02	<0.001
Congruent | Fake | Populistic vs. Incongruent | True | Sober	−0.09	1.42	0.991
Congruent | Fake | Populistic vs. Incongruent | True | Populistic	0.35	5.31	<0.001
Congruent | Fake | Populistic vs. Incongruent | Fake | Sober	0.49	7.03	<0.001
Congruent | Fake | Populistic vs. Incongruent | Fake | Populistic	0.73	10.71	<0.001
Incongruent | True | Sober vs. Incongruent | True | Populistic	0.45	11.39	<0.001
Incongruent | True | Sober vs. Incongruent | Fake | Sober	0.58	12.05	<0.001
Incongruent | True | Sober vs. Incongruent | Fake | Populistic	0.82	14.36	<0.001
Incongruent | True | Populistic vs. Incongruent | Fake | Sober	0.14	3.50	0.016
Incongruent | True | Populistic vs. Incongruent | Fake | Populistic	0.37	8.80	<0.001
Incongruent | Fake | Sober vs. Incongruent | Fake | Populistic	0.24	7.73	<0.001

DF = 199.

actual disinformation on the topic of interest. Thus, the main function of the carriers is to introduce actual disinformation to the discourse on the topic of interest. Indeed, a brief browse of the Internet gives many examples of fake news designed in this way, e.g., that coronavirus has been developed in Ukrainian biolaboratories (16), that Ukrainian president Volodymyr Zelensky is a cousin of Hungarian-born American businessman, and philanthropist supporting progressive and liberal political causes, George Soros (17) or that migrants are spreading new variants of coronavirus (18).

Limitations

It is essential to report that in the case of several experimental groups, we proceeded with ANOVA, despite the data distribution not being entirely normal, as indicated by the Kolmogorov–Smirnov normality test. Although the normality of the distribution is one of the assumptions of ANOVA, as postulated by Meyers and Well, breaking this assumption should not increase the type I error rate. This is due to the effect of the central limit theorem, which states that the distribution of means and their differences will tend to be normal as sample size increases, even when the distribution of the parent population is not (19, 20).

In studies that heavily rely on p-values as a measure of statistical significance, it is important to consider the limitations associated with this approach (21, 22). Relying solely on p-values can lead to potential misinterpretations and misuse of statistical results. It is crucial to recognize that p-values do not provide a complete picture of the magnitude or practical significance of an effect. Other statistical measures, such as effect sizes and confidence intervals, should be taken

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into account for a more comprehensive understanding of research findings. The dichotomous interpretation of "significant" and "non-significant" results based solely on p-values can oversimplify the complexity of the data. A more nuanced and rigorous approach to statistical analysis is necessary, which involves considering multiple statistical measures and avoiding an exclusive reliance on p-values. Given the nature of the current article as a short report, the comprehensive analysis and considerations discussed above regarding the limitations of p-values were not extensively applied. Future studies or more in-depth analyses can be undertaken to explore these limitations more extensively.

Finally, it is important to note that susceptibility to misinformation is a highly intricate and interconnected phenomenon that involves both psychocognitive mechanisms and contextual factors about the information. In this study, we attempted to capture some, but certainly not all, of the information features without controlling for any of the psychocognitive mechanisms. As a result, the findings and conclusions should be cautiously generalized, if applicable at all.

Future directions and conclusion

A number of further avenues of research revolve around these results. First, it would be desirable to confirm these findings using behavioral measures in real-world social media rather than simulations. While it is not ethically acceptable to run experimental studies, by posting false information on social media, it would be possible to do real-world observational work. For example, using a combination of online questionnaires and machine learning methods, one could analyze the past social media sharing behavior of Twitter or Facebook users in the context of the Trojan Horse type of information. For example, some machine learning experts are currently trying to implement psycholinguistic models in the field of misinformation research (23–25). Another research avenue involves the determination of reasons for knowingly sharing information that is false but congruent with the worldview. Without understanding the cognitive and psychological mechanisms of this behavioral engagement, any interventions aimed at reducing sharing behavior are unlikely to be successful.

The results of this study have practical implications for both researchers and public health institutions. First, it is crucial for researchers to distinguish susceptibility to misinformation based on veracity ratings from behavioral engagement with misinformation. This distinction is vital since the presented results showed that different information factors involve these two types of susceptibility. Additionally, our previous research results (11) pointed to the same importance of susceptibility differentiation from a psychocognitive perspective. Second, as many other studies on fake news concluded, political partisanship is one of the most important factors when deciding about information's truthfulness and willingness to engage with it (26). In this study, we showed that not only political beliefs but also prior beliefs about the COVID-19 pandemic tend to influence susceptibility to misinformation. One of the practical applications of these results might be used during health and vaccination campaigns. Specifically, perhaps instead of debunking maladaptive beliefs, better results could come from an approach that addresses these beliefs with compassion and understanding of individual worldviews.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: all data analyzed in this study have been made publicly available via Jagiellonian University Repository, and can be accessed https://doi.org/10.26106/fmdt-fp50.

Ethics statement

The study was conducted in accordance with all legal requirements regarding the conduct of scientific research of the Kingdom of Norway and the guidelines laid down in the Declaration of Helsinki. Consent was obtained from all subjects. The identical study design was approved by the Bioethics Committee of the Jagiellonian University in Krakow, Poland (1072.6120.66.2021). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MP designed the news items and the study procedure, conducted the study and statistical analysis, and wrote the draft of the manuscript. KN designed the news items and the study procedure, supervised the statistical analysis, and revised the manuscript. AG designed the news items and the study procedure, conducted the study, and revised the manuscript. JK designed the news items and the study procedure, supervised the statistical analysis, revised the manuscript, and received the funds. MM revised the manuscript and received the funds. JP revised the manuscript and received the funds. RR designed the news items and the study procedure, conducted the statistical analysis, wrote the draft of the manuscript, and received the funds. All authors approved the version to be published and agreed to be accountable for all aspects of the study in ensuring that questions related to the accuracy or integrity of any part of the study are appropriately investigated and resolved.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Cognitive Processes and Personality Traits Underlying Four Phenotypes of Susceptibility to (Mis)Information

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Misinformation on social media poses a serious threat to democracy, sociopolitical stability, and mental health. Thus, it is crucial to investigate the nature of cognitive mechanisms and personality traits that contribute to the assessment of news items' veracity, failures in the discernment of their truthfulness, and behavioral engagement with the news, especially if one wants to devise any intervention to stop the spread of misinformation in social media. The current research aimed to develop and test a 4-fold taxonomy classifying people into four distinct phenotypes of susceptibility to (mis)information. In doing so, it aimed to establish differences in cognitive and psychological profiles between these phenotypes. The investigated cognitive processes included sensitivity to feedback, belief updating, and cognitive judgment bias. Psychological traits of interest included the Big Five model, grandiose narcissism, anxiety, and dispositional optimism. The participants completed online surveys that consisted of a new scale designed to classify people into one of four phenotypes of susceptibility to (mis)information, advanced cognitive tests, and reliable psychological instruments. The four identified phenotypes, Doubters, Knowers, Duffers, and Consumers, showed that believing in misinformation does not imply denying the truth. In contrast, the numerically largest phenotypes encompassed individuals who were either susceptible (Consumers) or resistant (Doubters), in terms of veracity judgment and behavioral engagement, to any news, regardless of its truthfulness. Significantly less frequent were the phenotypes characterized by excellent and poor discernment of the news' truthfulness (the Knowers and the Duffers, respectively). The phenotypes significantly differed in sensitivity to positive and negative feedback, cognitive judgment bias, extraversion, conscientiousness, agreeableness, emotional stability, grandiose narcissism, anxiety, and dispositional optimism. The obtained results constitute a basis for a new and holistic approach in understanding susceptibility to (mis)information as a psycho-cognitive phenotype.

Keywords: cognitive, personality, psychological, phenotype, susceptibility, fake news, misinformation, anxiety

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INTRODUCTION

The problem of misinformation has received increasing research interest as events such as the 2016 United States presidential elections or the Brexit referendum in Great Britain drew attention to the power of fake news in influencing public opinion about highly consequential issues (1). Together with the COVID-19 outbreak, the beginning of 2020 has born wild conspiracy theories. For instance, several theories focused on Bill Gates, alleging that he created the virus himself, had patented the cure and was conspiring to use a coronavirus vaccine as a ploy to monitor people through an injected microchip or quantum-dot spy software (2). These false claims proliferated and gradually flooded the media and mainstream. Indeed, for the individuals and organizations involved in the spread of such misinformation, the pandemic became a gilded opportunity. They started capitalizing on both the many unknowns about the SARS-CoV-2 virus and the disease it causes, as well as many legitimate questions about the safety and efficacy of vaccines developed at unprecedented speed (2). Although now, almost 2 years later, we know much more about the origin and mechanism of this misinformation (3), our knowledge about the cognitive and psychological factors responsible for susceptibility to this kind of news still remains scarce. Thus, an important research challenge may be to determine how people assess the truthfulness of information and how those decisions may be associated with their psychological predispositions. Below, we present several diverse cognitive and psychological factors that may be important when investigating the individual differences in susceptibility to fake news in the context of social media, where individuals are not only passive recipients of information but can also actively engage with news items by liking and sharing them with other users.

Deciding whether to believe information involves several cognitive and motivational processes, including the ability to differentiate between truth and falsehood based on analytical and reflective reasoning, the ability to update beliefs in response to new information, sensitivity to positive and negative reinforcement, and optimistically/pessimistically biased judgment. The role of analytical and reflective reasoning in veracity judgment has been recently demonstrated experimentally by several studies. They show that people are able to override incorrect intuitions via analytical thinking (4–6) and those who do not reflect sufficiently on their prior knowledge often fail to discern truth from falsehood (7). Surprisingly, the role of the other abovementioned, affect-dependent cognitive processes (8), although intuitive, to the best of our knowledge has never been established experimentally. For example, a reduced ability to update beliefs in response to information that is concordant/discordant with people's partisanship may lead to a false valuation of certain news as true or false based on their cognitive utility (9) Similarly, affect-dependent changes in sensitivity to feedback and pessimistic/optimistic judgment bias could reduce the ability to correctly infer truthfulness based on the affective utility of the information.

Individual schemas of cognitive processes, along with emotional and behavioral patterns, constitute a more general concept of personality (10). Various personality traits have been postulated to be involved in the way we process information (11), yet there have been very few attempts to explain the role of personality differences in the susceptibility to misinformation (12). It is rather puzzling given that the Big Five personality traits, extraversion, conscientiousness, agreeableness, openness to experience, and neuroticism [the Five-Factor Model (13)], as well as anxiety, understood as a stable personality characteristic (14, 15), have the potential to shape humans' perception of truthfulness. Moreover, grandiose narcissism (16) and optimism (17) might influence behavioral engagement, e.g., information sharing. Indeed, agreeableness, conscientiousness, and openness to experience have already been proven to negatively correlate with the perceived reliability of political misinformation (18). A similar correlation was observed following a procedure of anxiety induction (19), which decreased the perceived reliability of false information. In turn, research on narcissism has provided some indirect evidence suggesting that "self-lovers" might be more susceptible to "alternative" facts (20). Given this broad spectrum of possible interrelations, it is surprising how limited our knowledge is of the links between personality traits and susceptibility to (mis)information.

The constant evaluation of information is a fundamental process of human cognition and is integral to learning, social engagement, and decision-making (9, 21, 22). As such, susceptibility to fake news should not be investigated in isolation but should be considered in the broader context of overall susceptibility to information, which can be operationalized as judgment of its veracity and behavioral interaction with it (e.g., liking, sharing on social media) (6, 23). Here, we propose a framework that is based on the simultaneous analysis of susceptibility to true and fake news and identification of four patterns of this susceptibility: (1) susceptible to any kind of information, regardless of its truthfulness, (2) susceptible only to true news and unsusceptible to fake news; (3) susceptible only to fake news and insensitive to the truth; and (4) susceptible to any kind of information, regardless of its truthfulness. These patterns could be operationalized as the following phenotypes: (1) Consumers; (2) Knowers; (3) Duffers, and (4) Doubters (**Figure 3**). Such a framework offers a structure for characterizing and quantifying individual differences in susceptibility to (mis)information and allows for a nuanced test of its underlying cognitive and psychological traits.

In the present study, using Prolific Academic linked with Qualtrics and Millisecond Inquisit web testing platforms, we recruited a sample of participants and assessed their suscpetibiliy to various true and false news regarding the COVID-19 pandemic. Based on this assessment, we classified each participant into one of the four phenotypes of information susceptibility: Consumers, Knowers, Duffers, and Doubters. The participants were further tested with regard to the abovementioned cognitive processes using experimental paradigms, such as the Ambiguous-Cue Interpretation test [ACI (24)], assessing cognitive judgment bias, the Probabilistic Reversal Learning test [PRL (25)], measuring sensitivity to positive and negative reinforcement and cognitive flexibility, and the Belief Updating Test [BUT (26)], measuring asymmetry

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in updating one's beliefs based on the type of information obtained. Participants were also tested with regard to their personality traits using questionnaires including the Life Orientation Test-Revised [LOT-R (17)] allowing measurement of dispositional optimism; the Ten-Item Personality Inventory [TIPI (27)] assessing the Big Five personality traits (extraversion, conscientiousness, agreeableness, openness to experience and neuroticism); the Trait Anxiety Scale [TAS (14)] measuring their level of dispositional anxiety; the Grandiose Narcissism Scale [GNS (28)] evaluating self-perceived authority, self-sufficiency, superiority, vanity, exhibitionism, entitlement, and exploitativeness; and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire [SPSRQ-RC (29)] and the BIS/BAS (behavioral inhibition system/behavioral activation system) Scale (30), which were aimed at self-assessment of reinforcement sensitivity.

MATERIALS AND METHODS

Participants

A power analysis using G*Power 3.1 (31) indicated that a total sample of 172 participants would give 90% power to detect medium effects (f = 0.5) in an analysis of differences between phenotypes of sensitivity to (mis)information using t-test, at an alpha of 0.05. Participants were recruited by Prolific Academic. During the Prolific prescreening stage, we excluded participants who had declared any hearing or vision difficulties or had no access to a computer, which was necessary for performing cognitive tests. To receive reliable answers, we recruited only the people who had previously participated in a minimum of 100 studies, with an acceptance rate of ≥95% for the submitted surveys. Additionally, we limited the number of previous participations to 500 to avoid people who had already conducted a high number of surveys. During the survey, the participants had to pass four attentional checks ("*It is important that you pay attention to this study. Please tick 'Somewhat agree'*") and all participants answered all checks correctly. The targeted number of participants was 200 adult Americans; however, due to dropouts as a result of technical problems during the experiment ($n = 16$), we analyzed data for $N = 184$ ($M_{Age} = 29.9$, SD = 8.73). The final sample included 87 males, 87 females, and 8 non-binary people (**Figure 1A**). Two participants did not fill in the demographic data but were included in the analysis. The majority of participants ($n = 169$) declared that the COVID-19 pandemic is a danger (on a Likert scale 1–3), while the remaining 13 people declared that they believed the COVID-19 pandemic is a hoax (on a Likert scale 4–6, **Figure 1B**). The majority of people lived in a city (**Figure 1C**). The majority declared their ethnicity White/Caucasian, followed by African American, Hispanic, Asian, Jewish, Native American, Arab, Pacific Islander, and other (see **Figure 1D**). The highest level of completed education was a bachelor's degree, followed by some college but no degree, high school, master's degree, associate degree, doctoral degree, less than high school, and professional degree (**Figure 1E**). The participants were also asked about their political orientation—the majority of the sample (**Figure 1F**) had

a left-wing orientation (on a scale from 0—left-wing to 10—right-wing, scoring 0 to 3), followed by centric (scoring from 4 to 6), and right-wing (scoring from 7 to 10).

Susceptibility to (Mis)Information Scale

The susceptibility to (mis)information was measured using a newly created scale based on 24 news headlines in a Facebook-like format. The topic of the news was connected to the COVID-19 pandemic. Half of the news presented true information, which was obtained from research reports and official World Health Organization guidelines and statistics (32). The other half presented fake information, which was created by the research team. Examples of true news and fake news are shown in **Figure 2**, and the whole scale can be accessed at (33).

Susceptibility to information was defined on two levels. The participants were asked to evaluate each item on the scale in terms of its veracity ("*Do you think the news above is true?*", where 1 was "*definitely false*" and 6 was "*definitely true*"), and the probability of engagement with it (willingness to like ("*On social media, I would give a 'like' to this news*", where 1 was "*totally disagree*" and 6 was "*totally agree*"), and willingness to share ("*I would share this news on my social media profile,*" where 1 was "*totally disagree,*" and 6 was "*totally agree*"). There was a positive correlation between willingness to share and willingness to like (for fake items: r = 0.88, P < 0.001; for true items: r = 0.91, P < 0.001).

By averaging the scores of all true news and fake news items, four variables emerged: true news veracity judgment (Cronbach's α = 0.73), fake news veracity judgment (Cronbach's α = 0.68), engagement with true news rating (Cronbach's α = 0.93), and engagement with fake news rating (Cronbach's α = 0.88).
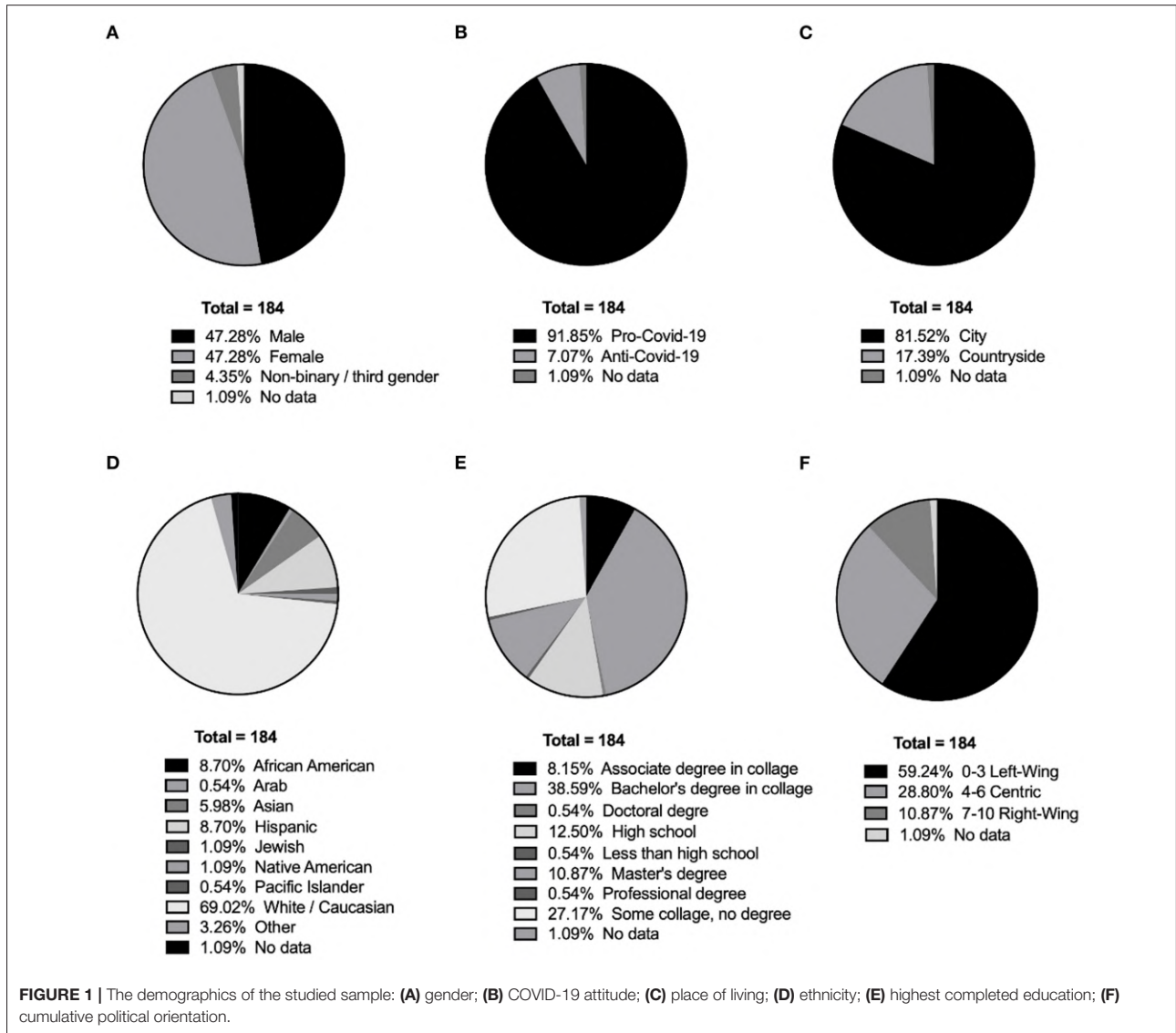
Phenotypes of Susceptibility to (Mis)Information

Based on the scores from SIS and a median split of the averaged true and averaged fake news veracity ratings, each participant was assigned to one of the four phenotypes of (mis)information susceptibility: Consumers (the people highly rating the veracity of any kind of information, regardless of its truthfulness), Knowers (the ones highly rating the veracity of true news and low rating the veracity of fake news), Duffers (opposite to the knowers: highly rating the veracity of fake news and low rating the veracity of true news), and Doubters (the people evaluating all news as untrustworthy). The same classification was conducted based on engagement with the news scores. Thus, this resulted in the differentiation of two separate types of phenotypic classification, one based on veracity and the other on engagement ratings (**Figure 3**).

Cognitive Tests
Ambiguous Cue Interpretation

To experimentally evaluate cognitive judgment bias (optimism/pessimism), the participants were tested using the ACI test. This procedure was adapted from Schick et al. (24) and modified for online testing. In this experimental paradigm, participants initially learned to discriminate two stimuli (tones of different frequencies of either 1,164 or 1,000 Hz), which acquired

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FIGURE 1 | The demographics of the studied sample: **(A)** gender; **(B)** COVID-19 attitude; **(C)** place of living; **(D)** ethnicity; **(E)** highest completed education; **(F)** cumulative political orientation.

emotional and motivational value due to subsequent feedback (gaining points or avoidance of losing points). Following the tone predicting a reward, the participants had to press a symbol on the computer screen (square) to obtain one point. By the same token, following the tone predicting a punishment, the participants had to press another symbol (circle) to avoid losing one point. The tones were counterbalanced across the subjects. After this acquisition phase, the test phase introduced ambiguous stimulus (a tone of intermediate frequency-—1,078 Hz—to the tones predicting reward and punishment). The reaction to this tone (choosing the square or circle) served as a measure of judgment bias, indicating the participants' expectation of rewarding or potentially punishing effects of their decision (**Figure 4**). The testing phase consisted of 30 trials in total, 10 trials for each tone: rewarding, punishing, and ambiguous, presented in a pseudorandom order. During ACI testing, the responses to

each tone (positive, ambiguous, and negative) were scored and analyzed as the proportion of the total number of responses to a given tone. To calculate the cognitive bias index, the proportion of negative responses to the ambiguous cues was subtracted from the proportion of positive responses, resulting in values ranging between −1 and +1, where values above 0 indicate an overall positive judgment and "optimistic" interpretation of the ambiguous cue.

Belief Updating Test

To further test whether an optimistic bias could differ in phenotypes of susceptibility to (mis)information, participants completed a Belief Updating Test (BUT) (26). During the test, participants provided estimates of their likelihood of experiencing 10 different types of adverse life events (e.g., Alzheimer's disease, robbery). After each trial, they were
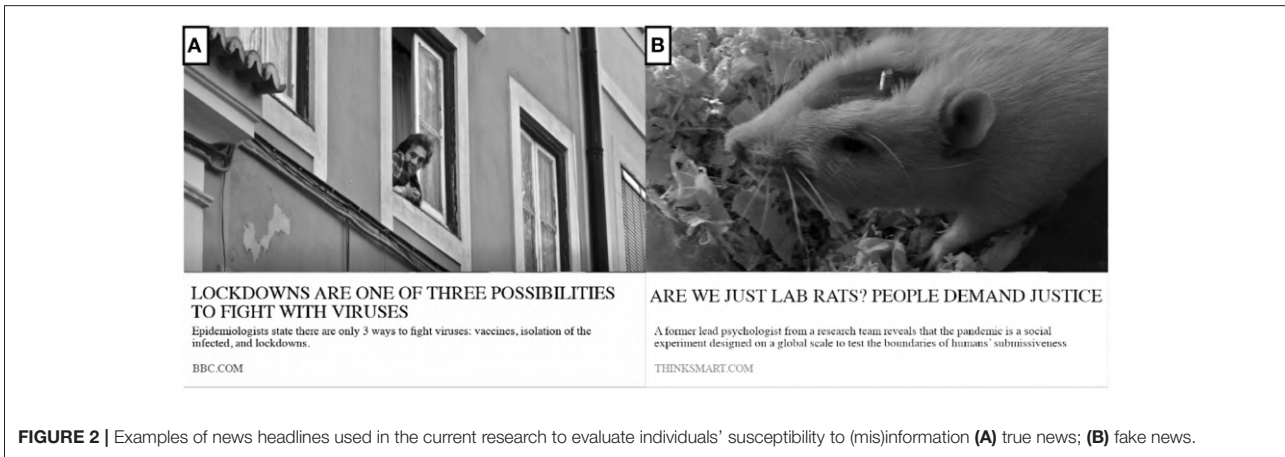
FIGURE 2 | Examples of news headlines used in the current research to evaluate individuals' susceptibility to (mis)information **(A)** true news; **(B)** fake news.
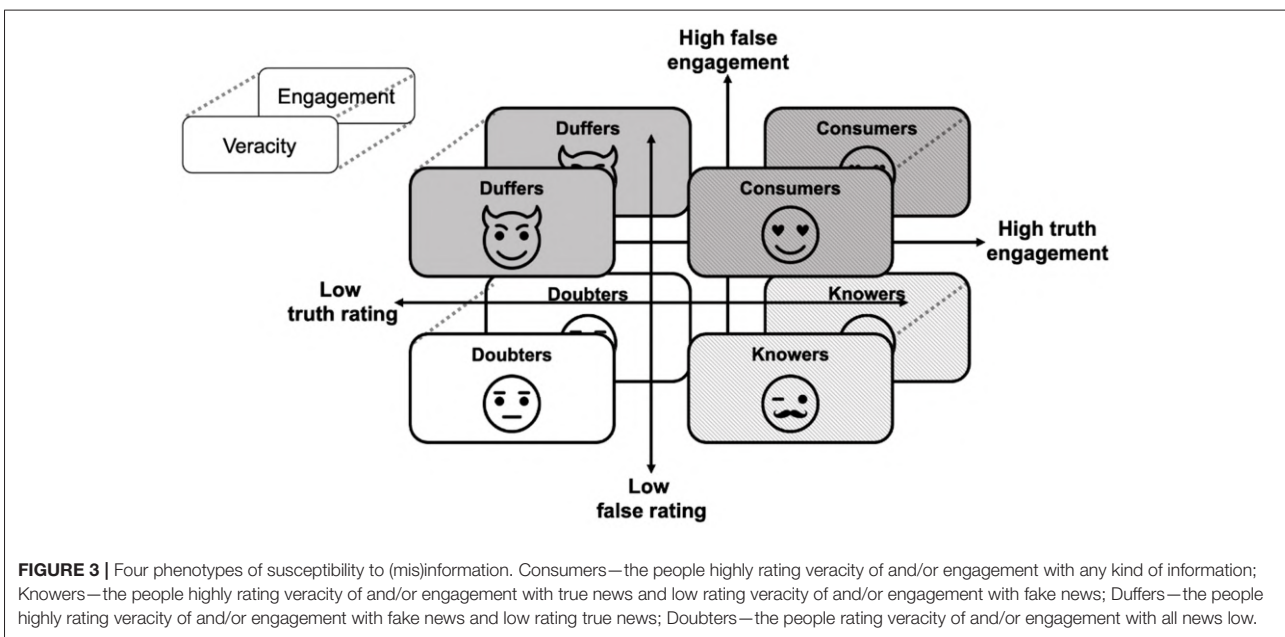

FIGURE 3 | Four phenotypes of susceptibility to (mis)information. Consumers—the people highly rating veracity of and/or engagement with any kind of information; Knowers—the people highly rating veracity of and/or engagement with true news and low rating veracity of and/or engagement with fake news; Duffers—the people highly rating veracity of and/or engagement with fake news and low rating true news; Doubters—the people rating veracity of and/or engagement with all news low.

presented with a pseudoactual probability of that event occurring to an average person in their environment. Subsequently, the ability of participants to use this information to update their predictions was assessed by asking them again for their estimates (**Figure 5**). The abovementioned pseudoactual probability was calculated by a simple equation y = 1.22x for half of the events and y = 0.78x for the other half (y—the feedback information, x—the first estimation). The first equation makes the feedback 22% higher than the estimated probability, whereas the second one lowers it by 22%. Unlike 20 or 25%, the chosen values lowered the risk that the participants would realize the mechanism behind the test. Additionally, this approach was used to avoid the complexity of estimating the actual probability of certain events under individual circumstances and to ensure that half of the presented probabilities were optimistic (for y = 0.78) and the other half was pessimistic (y = 1.22x). The belief
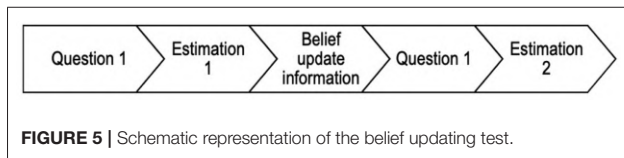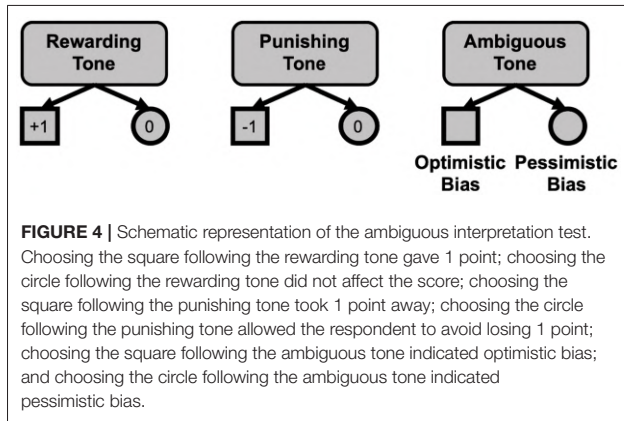
updating scores were calculated using the following equation for each event:

$$O = -1^* \frac{E2 - E1}{E1 - 0.78E1}$$

$$P = -1^* \frac{E2 - E1}{E1 - 1.22E1}$$

where O is Optimistic belief updating, P is Pessimistic Belief Updating, E1 is First estimation, and E2 is Second estimation.

For O or $P = 0$, no belief update occurred. For O or $P = 1$, the belief update relied completely on the feedback. When O or $P > 0$ and <1, the update partially relied on the feedback. When O or $P > 1$, the update exceeded the feedback, and when O or $P < 0$, the update was negatively modulated by the feedback. The final two scores Pessimistic Belief Updating Index and Optimistic

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FIGURE 4 | Schematic representation of the ambiguous interpretation test. Choosing the square following the rewarding tone gave 1 point; choosing the circle following the rewarding tone did not affect the score; choosing the square following the punishing tone took 1 point away; choosing the circle following the punishing tone allowed the respondent to avoid losing 1 point; choosing the square following the ambiguous tone indicated optimistic bias; and choosing the circle following the ambiguous tone indicated pessimistic bias.

FIGURE 5 | Schematic representation of the belief updating test.

Belief Updating Index were calculated as the means from the respective events.

Probabilistic Reversal Learning
To test how sensitivity to feedback differs in susceptibility to (mis)information, the participants completed the Probabilistic Reversal Learning (PRL) (25).

In this task, for each trial, two stimuli (abstract, complex, colorful patterns on a computer screen, an example is presented in **Figure 6**) were presented simultaneously on the left and right sides of the screen (location randomized). Using trial-and-error feedback after each response, participants learned to select the stimulus that was usually correct (rewarded on 80% of trials and punished or unrewarded on 20% of trials) and to avoid the stimulus that was usually incorrect (punished or unrewarded on 80% of trials and rewarded on 20% of trials). Responses were made by pressing the "E" or "I" button on a computer keyboard. On each individual trial, the stimuli were presented for 2,000 ms within which the response had to be made (or else a "too late" message was presented). Rewards and punishments were symbolic, in the form of a green smiley face for correct responses or a red sad face for incorrect responses, appearing together with the words "correct" or "incorrect" onscreen after each choice. The rules intermittently reversed (after 10 consecutive choices of the usually rewarded patterns) such that the stimulus that was usually rewarded became usually punished and vice versa. Consequently, participants had to adjust their responses to gain the reward and avoid punishment. On a minority of trials (20%), false-negative and false-positive feedback was provided to correct and incorrect responses, respectively, the so-called "probabilistic errors." Participants performed three successive blocks of the task, each lasting 5 min. The use of probabilistic reinforcement increased the complexity of the task in such a way that the
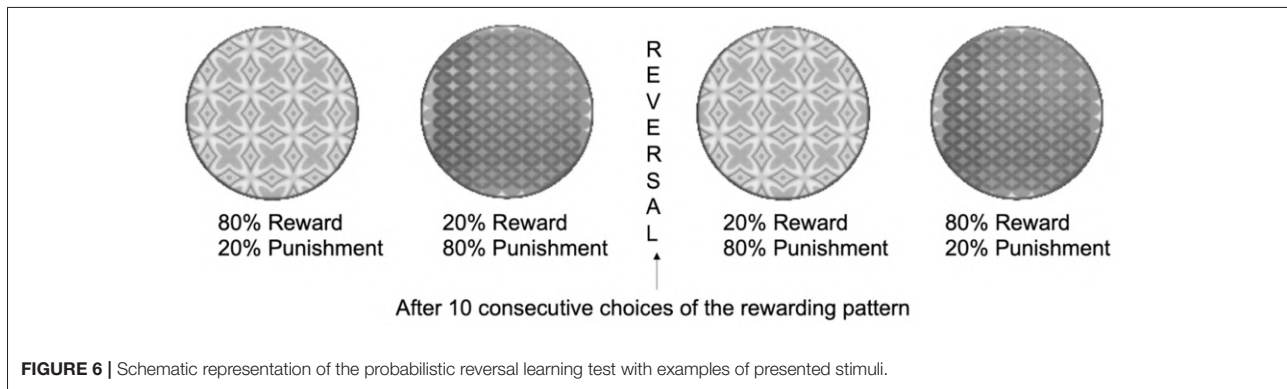
information from any given choice was insufficient to guide future behavior, and participants must have engaged cognitive functions to track the reward and punishment history for both stimuli to determine the stimulus that is more beneficial overall. For successful completion of the task, participants had to learn to ignore infrequent and misleading negative and positive feedback that arose from the probabilistic nature of the discrimination.

Four types of events were analyzed using this task: (1) a correct response followed by positive feedback, (2) a correct response followed by negative feedback (probabilistic punishment), (3) an incorrect response followed by negative feedback, and (4) an incorrect response followed by positive feedback (probabilistic reward). These four types of events were then subjected to the Win-shift/Lose-shift analysis, where behavior was analyzed according to the outcome of each preceding trial to assess the sensitivity of participants to positive and negative feedback. Rewarded outcomes followed by a decision to shift the response (Win-shifts) were counted separately for the correct and incorrect responses and expressed as a ratio of all rewarded outcomes on a given stimulus. These Win–shifts ratios were used as a measure of sensitivity to either true (if the rewarding outcome followed the choice of the correct stimulus) or misleading (if the rewarding outcome followed the choice of the incorrect stimulus) positive feedback (the smaller the ratio was, the higher sensitivity to positive feedback). Conversely, Lose-shift ratios were calculated by dividing punishing outcomes after which the subject changed the choice by the total number of punished trials on a given stimulus. These Lose-shift ratios represented sensitivity to either true (when the punishing outcome followed the choice of the incorrect stimulus) or misleading (when the punishing outcome followed the choice of the correct stimulus) negative feedback (the higher the ratio was, the higher the sensitivity to negative feedback). Additionally, by consecutively choosing 10 correct patterns, the participants achieved reversal. The number of achieved reversals indicated cognitive flexibility, as it requires the participants to be able to notice and adapt to constantly changing rules of the test (**Figure 6**).

Personality Questionnaires
Ten Item Personality Inventory
To evaluate the differences between the phenotypes in the Big Five personality traits: extraversion, emotional stability, conscientiousness, agreeableness, and openness to experience [Five-Factor Model (13)], the previously phenotyped participants completed the Ten Item Personality Inventory (TIPI) (27). In this questionnaire, each trait (e.g., extraversion – "*I see myself as extraverted, enthusiastic*") is defined by a mean score of answers to two questions given on a 7-point Likert scale [1—"*disagree strongly*," 7—"*agree strongly*"; (one item from each pair is reverse-coded]. The mean scores for each trait and correlation values between the items from each pair were for extraversion: 3.10 ± 1.63; $r = 0.62$, $P < 0.001$, for emotional stability 4.21 ± 1.53; $r = 0.50$, $P < 0.001$, for conscientiousness: 4.89 ± 1.57; $r = 0.58$, $P < 0.001$, for agreeableness: 4.38 ± 1.16; $r = 0.24$, $P < 0.001$, and for openness: 5.08 ± 1.27; $r = 0.29$, $P < 0.001$.

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FIGURE 6 | Schematic representation of the probabilistic reversal learning test with examples of presented stimuli.

Trait Anxiety Scale

To test the differences between the phenotypes in trait anxiety, the subjects were evaluated using the Trait Anxiety Scale (TAS) (14), adapted from its original Polish version (*pl. Skala Leku-Cecha, SL-C*). It is a 15-item questionnaire (15 items, e.g., "*I am afraid of failure*"; mean = 27.72 ± 8.81; Cronbach's α = 0.90; 4-point scale: "0—*never,*" "1—*seldom,*" "2—*sometimes,*" "3—*often*") constructed to evaluate individuals' anxiety as a constant personality trait, which is defined as a tendency to perceive situations as dangerous or to expect future events to be threatening, which manifests by characteristic cognitive, affective, behavioral and somatic symptoms.

Grandiose Narcissism Scale

To measure the differences between the phenotypes in grandiose narcissism, the participants completed the Grandiose Narcissism Scale (GNS) (28). The scale consists of 33 questions (mean = 102 ± 22.87; Cronbach's α = 0.93), divided into 7 subscales: authority (e.g., "*I like to be in charge of things*"; mean = 16.81 ± 6.57; Cronbach's α = 0.94) as a preference to be in charge, self-sufficiency (e.g., "*I don't rely on other people to get things done*"; mean = 21.61 ± 4.08; Cronbach's α = 0.78) as a preference to work on one's own, superiority (e.g., "*I'm more talented than most other people*"; mean = 11.79 ± 4.32; Cronbach's α = 0.87) as thinking to be better than others, vanity (e.g., "*I care about how good I look*"; mean = 18.90 ± 5.37; Cronbach's α = 0.91) as paying attention to one's physical appearance, exhibitionism (e.g., "*I do things that grab people's attention*"; mean = 12.31 ± 4.81; Cronbach's α = 0.86) as a need to attract others' attention, entitlement (e.g., "*I expect to be treated better than average*"; mean = 10.90 ± 3.96; Cronbach's α = 0.81) as a desire of special treatment, and exploitativeness (e.g., "*I can be pretty manipulative*"; mean = 10.52 ± 4.78; Cronbach's α = 0.9) as a tendency to use others for personal gains. The items were presented in random order. The answers were given on a 6-point Likert scale, where 1 was "*strongly disagree,*" and 6 was "*strongly agree.*"

Life Orientation Test—Revised

To test whether phenotypes of susceptibility to (mis)information differ in dispositional optimism, the participants completed the Life Orientation Test—Revised (LOT-R) (17). This brief questionnaire consists of 10 items (e.g., "*In uncertain times, I usually expect best*"; mean = 11.84 ± 5.08; Cronbach's α = 0.87) with possible answers given on a 5-point Likert scale, where 1 was "*strongly disagree*" and 5 -was "*strongly agree.*" Four of the items are so-called 'filters' (used to mask the real purpose of the questionnaire), which are not included in the final score. The score of this scale can be interpreted as dispositional optimism—a personality trait that makes people have favorable expectations about future events. The LOT-R is a self-assessment questionnaire measuring personal opinion in contrast to the ACI, which tests reactions to specific stimuli.

Sensitivity to Punishment Sensitivity to Reward Questionnaire-Revision and Clarification

To evaluate the differences between phenotypes in self-assessed sensitivity to punishment and reward, the participants completed the Sensitivity to Punishment Sensitivity to Reward Questionnaire-Revision and Clarification (SPSRQ-RC), described and validated in detail by Conner et al. (29). The SPSRQ-RC is a questionnaire that measures self-assessed sensitivity to reinforcement. It consists of 20 items, and the answers for each question are given on a 5-point Likert scale, where 1 is "*very untrue*" and 5 is "*very true*"). Summing up answers from items responding to sensitivity to reward (e.g., "*I do things for quick gains*"; mean = 24.82 ± 7.09; Cronbach's α = 0.81) and sensitivity to punishment (e.g., "*I am a shy person*"; *mean = 32.72 ± 9.39*; Cronbach's α = 0.9) gives general scores of these sensitivities.

Behavioral Inhibition System/Behavioral Activation System Scale

To further evaluate the differences, participants completed the Behavioral Inhibition System / Behavioral Activation System (BIS/BAS) Scale (30). BIS/BAS are the constructs from Gray's biopsychological theory of personality (34). BIS is a neural system that drives motivation to avoid punishment, novelty, and negative situations. BIS is responsible for negative emotions such as fear or anxiety, whereas BAS is a system that motivates participants to gain rewards, is goal-oriented, and is responsible for positive emotions. The BIS/BAS Scale is an empirical approach to measure individual differences in the level of sensitivity of the previously mentioned systems. It consists of 24
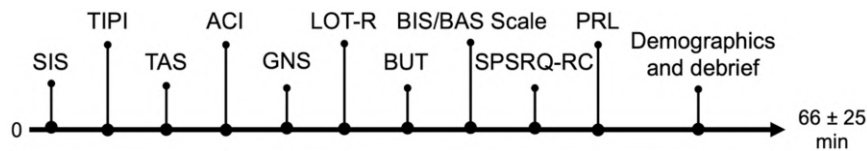
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FIGURE 7 | Schematic representation of the testing procedure. The tests were completed in the following order: SIS, Susceptibility to (mis)information scale; TIPI, Ten item personality inventory; TAS, Trait anxiety scale; ACI, Ambiguous cue interpretation test; GNS, Grandiose narcissism scale; LOT-R, Life orientation test revised; BUT, Belief updating test; BIS/BAS Scale, Behavioral Inhibition System/Behavioral Approach System scale; SPSRQ-RC, Sensitivity to punishment Sensitivity to reward questionnaire revision and clarification; PRL, Probabilistic reversal learning, and Demographic survey followed by a debrief.

items (four are fillers), each with 4-point scale answers, where 1 means *"very untrue for me,"* and 4 means *"very true for me."* The questionnaire consists of four different subscales that do not sum up to a single factor—BIS (e.g., *"I worry about making mistakes"*; mean = 22.00 ± 4.00; Cronbach's α = 0.81), BAS Drive (e.g., *"I go out of my way to get things done"*; mean = 10.10 ± 2.47; Cronbach's α = 0.77), BAS Reward Responsiveness (e.g., *"When I get something I want, I feel excited and energized"*; mean = 16.57 ± 2.53; Cronbach's α = 0.73), and BAS Fun Seeking (e.g., *"I crave excitement and new sensations"*; mean = 11.46 ± 2.33; Cronbach's α = 0.66).

Statistical Analysis

The data were analyzed using SPSS (version 25.0, SPSS Inc., Chicago, IL, USA). The normality of the data was verified using the Shapiro–Wilk test. To validate the four phenotypes of susceptibility to (mis)information, the differences between the groups of participants classified as susceptible/unsusceptible to true and fake news were analyzed using a two-way analysis of variances (ANOVA) with the between-subject factors of susceptibility to true news (high vs. low) and susceptibility to fake news (high vs. low), separately for veracity judgment and engagement with the news. The differences between the phenotypes were analyzed by planned comparisons between a) Duffers and Knowers and b) Consumers and Doubters using *t*-tests, or where normality was violated, using U Mann–Whitney's test. The planned comparison was done because Duffers and Knowers represent the axis of truth discernment, whereas Consumers and Doubters represent a general susceptibility to (mis)information. The descriptive statistics of every analysis can be found in **Supplementary Table 1**.

Procedure

The study was conducted between the 10th and 27th of August 2021. Eligible participants were recruited for the study via Prolific Academic, where they found essential information and instructions. Following informed consent, they were redirected to Qualtrics.com, where they completed the first part of the survey. In the second part of the study, they were asked to download the Millisecond Inquisit web application, where they completed the PRL test, and following completion of this task, they were redirected back to Qualtrics to fill in the demographic data and to be debriefed. The tests and questionnaires described in the previous paragraph were completed in the order presented in

Figure 7. The mean time of the survey to be completed was 65.9 min with SD = 25.30. All participants were paid £ 9.38.
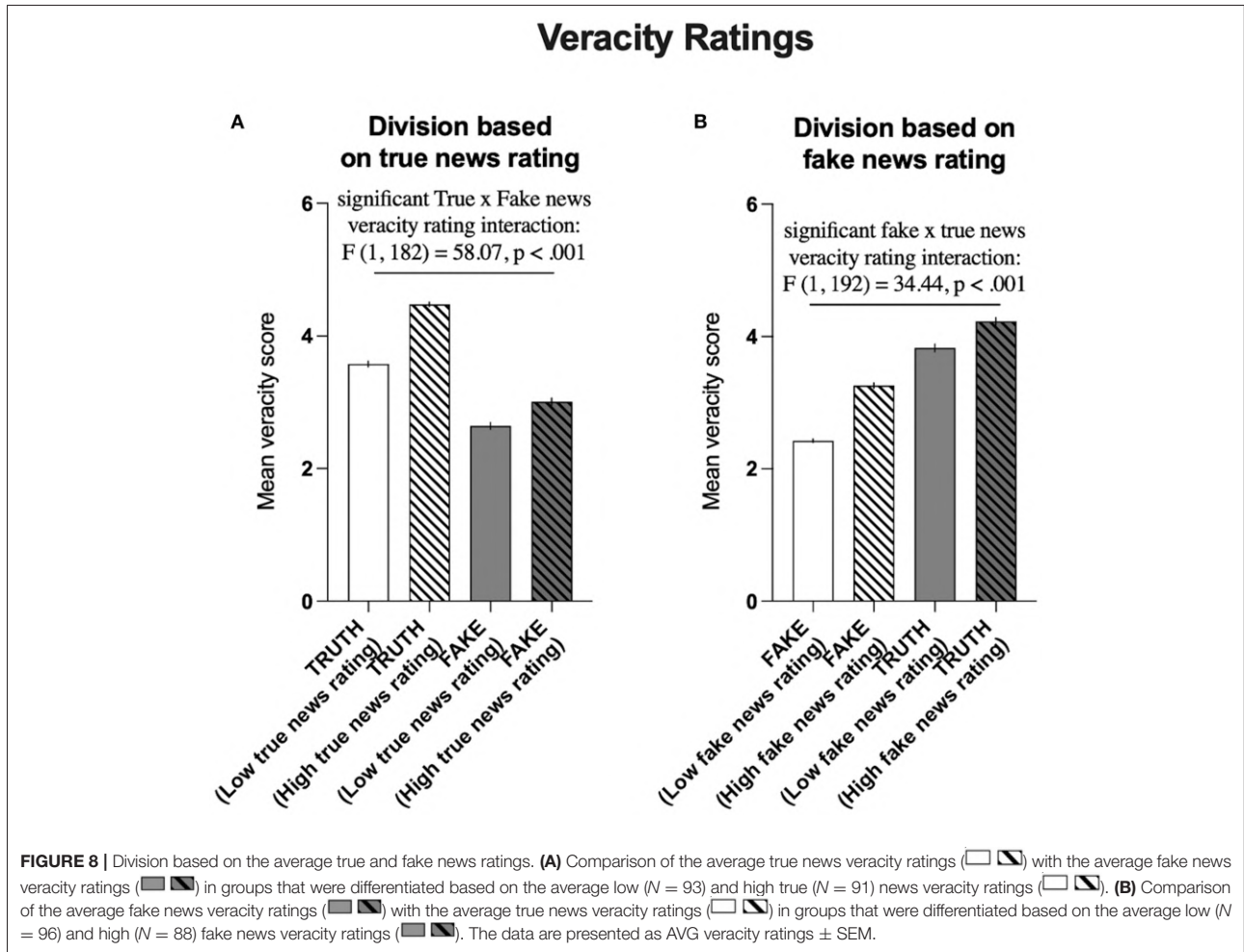
RESULTS

All data analyzed in this study have been made publicly available via Jagiellonian University Repository (33).

Susceptibility to (Mis)Information Scale
Veracity Judgment Ratings

The median split of true news veracity ratings resulted in the differentiation of two groups of participants: those with scores above the median (high truth rating) and those with scores below the median (low truth rating). Comparison of the true news veracity ratings with fake news veracity ratings in these groups revealed that in general, the true news was rated higher in terms of veracity than the fake news [$F_{(1,182)}$ = 1,175, P < 0.001]. It also revealed a generalized effect of the veracity rating group, i.e., Participants who highly rated the true news also highly rated fake news [$F_{(1,182)}$ = 127.3, P < 0.001]. Notably, the intergroup difference was significantly more pronounced for true news ratings than for fake news ratings [significant interaction: $F_{(1,182)}$ = 58.07, P < 0.001, **Figure 8A**].

Similarly, the median split of fake news veracity ratings resulted in the differentiation of another two groups of participants: those with scores above the median (high false rating) and those with scores below the median (low false rating). Comparison of the fake news veracity ratings with true news veracity ratings in these groups revealed that in general, the true news was rated higher in terms of veracity than the fake news [$F_{(1,182)}$ = 1,036, P < 0.001]. Moreover, it also revealed a generalized effect of news rating group, i.e., Participants who highly rated fake news also highly rated true news [$F_{(1,182)}$ = 177.8, P < 0.001]. Again, the intergroup difference was significantly more pronounced for fake news ratings than for true news ratings [significant interaction: $F_{(1,192)}$ = 34.44, P < 0.001, **Figure 8B**]. The significant statistical interactions between average scores of veracity in groups of highly/lowly rating true news and highly/lowly rating fake news validated the classification according to four phenotypes of (mis)information susceptibility based on veracity judgments.

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FIGURE 8 | Division based on the average true and fake news ratings. **(A)** Comparison of the average true news veracity ratings (□ ◼) with the average fake news veracity ratings (◼ ◼) in groups that were differentiated based on the average low ($N = 93$) and high true ($N = 91$) news veracity ratings (□ ◼). **(B)** Comparison of the average fake news veracity ratings (◼ ◼) with the average true news veracity ratings (□ ◼) in groups that were differentiated based on the average low ($N = 96$) and high ($N = 88$) fake news veracity ratings (◼ ◼). The data are presented as AVG veracity ratings ± SEM.

Engagement Ratings

Analogous to veracity ratings, the median split of the ratings of engagement with true news resulted in the differentiation of two groups of participants: those with scores above the median (highly engaged with true news) and those with scores below the median (unengaged with true news). Comparison of the ratings of engagement with fake news in these groups revealed that in general, the participants declared a higher rate of engagement with true news than with fake news [$F_{(1,182)} = 161.7$, P < 0.001]. It also revealed a generalized effect of engagement with the news group, i.e., participants declaring high engagement with the true news were also declaring high engagement with the fake news [$F_{(1,182)} = 303.5$, P < 0.001]. Notably, similar to the veracity ratings, the intergroup difference was significantly more pronounced for the declared engagement with true news than with the fake news (significant interaction: [$F_{(1,182)} = 77.09$, P < 0.001, **Figure 9A**].
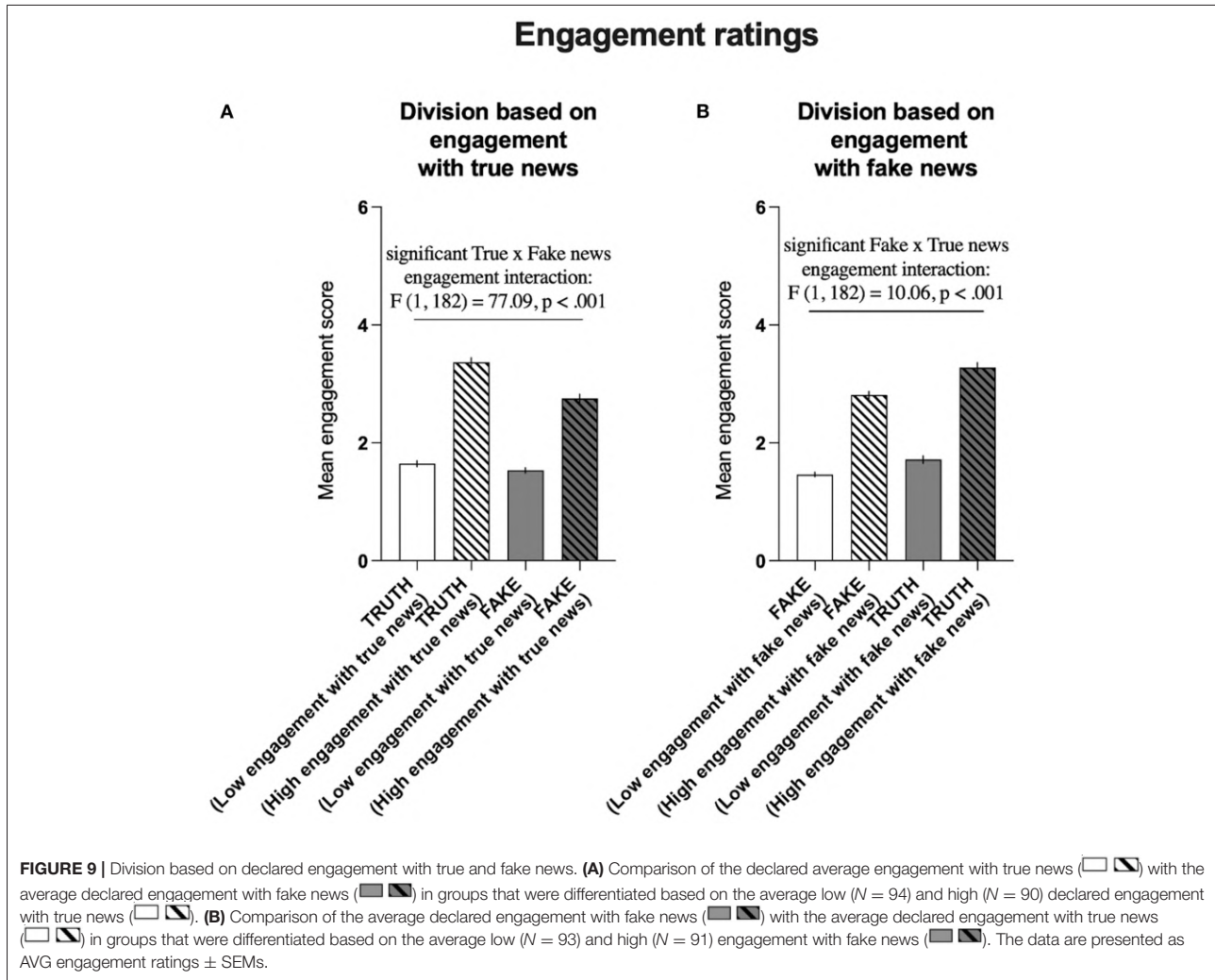
Similarly, the median split of the ratings of engagement with fake news resulted in the differentiation of two groups of participants: those with scores above the median (highly engaged with fake news) and those with scores below the median (unengaged with fake news). Comparison of the ratings of engagement with true news in these groups revealed that in general, the participants declared a higher rate of engagement with true news than with fake news [$F_{(1,182)} = 117.1$, P < 0.001]. It also revealed a generalized effect of engagement with the news group, i.e., participants declaring high engagement with the fake news were also declaring high engagement with the true news [$F_{(1,182)} = 285.2$, P < 0.001]. Again, similar to the veracity ratings, the intergroup difference was significantly more pronounced for the declared engagement with true news than with the fake news [significant interaction: $F_{(1,182)} = 10.06$, P < 0.001, **Figure 9B**].

The significant statistical interactions between average scores of engagement in groups of high/lowly rating true news and high/lowly rating fake news validated the classification according to four phenotypes of (mis)information susceptibility based on engagement with the news.

Frequency of Phenotypes of Susceptibility to (Mis)Information

Analysis of the phenotype distribution frequency in the investigated sample revealed that the most numerous were

FIGURE 9 | Division based on declared engagement with true and fake news. **(A)** Comparison of the declared average engagement with true news (☐ ◣) with the average declared engagement with fake news (▣ ◣) in groups that were differentiated based on the average low (N = 94) and high (N = 90) declared engagement with true news (☐ ◣). **(B)** Comparison of the average declared engagement with fake news (▣ ◣) with the average declared engagement with true news (☐ ◣) in groups that were differentiated based on the average low (N = 93) and high (N = 91) engagement with fake news (▣ ◣). The data are presented as AVG engagement ratings ± SEMs.

phenotypes of the Consumers ($N_{Veracity} = 53$, $N_{Engagement} = 76$) and the Doubters ($N_{Veracity} = 58$, $N_{Engagement} = 79$). Duffers and Knowers were significantly less numerous: Duffers ($N_{Veracity} = 35$, $N_{Engagement} = 15$) and Knowers ($N_{Veracity} = 38$, $N_{Engagement} = 14$).

Differences Between Phenotypes of Veracity Rating
Cognitive Tests
PRL

The analysis of the Win-shift/Lose-shift data from PRL tests revealed a lack of significant interphenotypic differences in sensitivity to positive feedback between Doubters and Consumers ($U = 1404$, $P = 0.43$), between Knowers and Duffers ($U = 490$, $P = 0.053$), in negative feedback between Doubters and Consumers ($U = 1,344$, $P = 0.26$), between Knowers and Duffers ($U = 593$, $P = 0.43$) and in cognitive flexibility between Doubters and Consumers [$t_{(109)} = 0.13$, $P = 0.90$] or between Knowers and Duffers [$t_{(71)} = 1.2$, $P = 0.23$].

ACI

The analysis of choices following ambiguous cues in the ACI paradigm revealed a lack of significant interphenotypic differences in cognitive judgment bias between Doubters and Consumers ($U = 1511$, $P = 0.88$) and between Knowers and Duffers ($U = 575.5$, $P = 0.32$).

BUT

The analysis of optimistic and pessimistic belief updating indices revealed a lack of significant interphenotypic differences in optimistic belief updating (Doubters vs. Consumers, $t_{(107)} = 0.99$, $P = 0.33$; Knowers vs. Duffers, $t_{(71)} = 0.14$, $P = 0.89$) and in pessimistic belief updating (Doubters vs. Consumers, $U = 1,334$, $P = 0.45$; Knowers vs. Duffers, $U = 604$, $P = 0.50$).

Psychological Self-Assessment Questionnaires
TIPI

The analysis of the 5-factor model from TIPI revealed that Consumers were more conscientious than Doubters ($U =$

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1083, P = 0.007; **Figure 10A**). There was no significant difference between Knowers and Duffers (U = 636.5, P = 0.76). Furthermore, no significant interphenotypic differences were revealed in extraversion (Doubters vs. Consumers, U = 1,351, P = 0.27; Knowers vs. Duffers, U = 628, P = 0.68), emotional stability (Doubters vs. Consumers, U = 1,265, P = 0.11; Knowers vs. Duffers, $t_{(71)}$ = 0.07, P = 0.95), agreeableness (Doubters vs. Consumers, U = 1,531, P = 0.97; Knowers vs. Duffers, $t_{(71)}$ = 1.172, P = 0.25) or openness to experience (Doubters vs. Consumers, U = 1,393, P = 0.391; Knowers vs. Duffers, U = 567.5, P = 0.28).

TAS
The TAS analysis revealed that Duffers were less anxious than Knowers (U = 444.5, P = 0.01; **Figure 10B**). There was no significant difference between Doubters and Consumers [$t_{(109)}$ = 1.123, P = 0.26].

GNS
The analysis of GNS revealed that Consumers had higher scores than Doubters in grandiose narcissism [$t_{(109)}$ = 3.03, P = 0.003; **Figure 10C**], authority (U = 1,193, P = 0.04; **Figure 10D**), superiority [$t_{(109)}$ = 2.13, P = 0.04; **Figure 10E**], vanity [$t_{(109)}$ = 3.38, P = 0.001; **Figure 10F**], and entitlement [$t_{(109)}$ = 3.35, P = 0.001; **Figure 10G**]. There were no significant differences between Consumers and the Doubters in self-sufficiency (U = 1,359, P = 0.29), exploitativeness (U = 1,374, P = 0.34) or exhibitionism (U = 1,423, P = 0.50). The analysis revealed no significant differences between Knowers and Duffers in grandiose narcissism [$t_{(71)}$ = 0.47, P = 0.65], authority [$t_{(71)}$ = 0.37, P = 0.71], superiority [$t_{(71)}$ = 0.79, P = 0.43], vanity [$t_{(71)}$ = 1.35, P = 0.18], entitlement [$t_{(71)}$ = 0.14, P = 0.89], self-sufficiency [$t_{(71)}$ =1.25, P = 0.22], exploitativeness (U = 575.5, P = 0.32), and exhibitionism [$t_{(71)}$ = 0.41, P = 0.68].

LOT-R
The analysis of LOT-R revealed no significant differences in dispositional optimism between Doubters and Consumers (U = 1,266, P = 0.11) or Knowers and Duffers (U = 624.5, P = 0.66).

BIS/BAS Scale
The analysis of variables from the BIS/BAS scale revealed that Consumers scored significantly higher than Doubters in BAS drive (U = 1,012, P = 0.002; **Figure 10H**) and BAS reward responsiveness (U = 1,152, P = 0.02; **Figure 10I**). There were no significant differences between these two phenotypes in BAS fun seeking [$t_{(109)}$ = 1.83, P = 0.07] or BIS (U = 1,329, P = 0.22). Furthermore, there were no significant differences between Knowers and Duffers in BAS Drive [$t_{(71)}$ = 0.12, P = 0.90], BAS reward responsiveness (U = 538.5, P = 0.16), BAS fun seeking [$t_{(71)}$ = 1.25, P = 0.22] and BIS (U = 501, P = 0.07).

SPSRQ-RC
The analysis of SPSRQ-RC revealed a lack of significant interphenotypic differences in sensitivity to reward (Consumers vs. Doubters, $t_{(109)}$ = 1.46, P = 0.15; Knowers vs. Duffers, $t_{(71)}$ = 0.82, P = 0.42) and in sensitivity to punishment [Consumers vs.

Doubters, U = 1,337, P = 0.24; Knowers vs. Duffers, $t_{(71)}$ = 0.63, P = 0.53].

Differences Between Phenotypes of Engagement Rating
Cognitive Tests
PRL
The analysis of the win-shift/lose-shift data from PRL tests revealed that, compared to Doubters, Consumers were less sensitive to positive feedback (U = 2,439, P = 0.04; **Figure 11A**), more sensitive to negative feedback [$t_{(153)}$ = 2,654, P = 0.009; **Figure 11B**], and less cognitively flexible, as indexed by fewer reversals (U = 2,373, P = 0.02; **Figure 11C**). Further analysis revealed a lack of significant differences between Knowers and Duffers in sensitivity to positive feedback (U = 104, P = 0.98), sensitivity to negative feedback [$t_{(27)}$ = 1.199, P = 0.24], and cognitive flexibility [$t_{(27)}$ = 0.32, P = 0.75].

ACI
Prescreening of the ACI data revealed the presence of 2 outliers (identified with the ROUT method), and these data were excluded from the analysis. In the ACI paradigm, Knowers more often identified the ambiguous tone as a cue predicting a reward than Duffers (U = 50, P = 0.04; **Figure 11D**). There was no significant difference between Consumers and Doubters (U = 2,817, P = 0.50).

BUT
The analysis of optimistic and pessimistic belief updating indices revealed a lack of significant interphenotypic differences between the groups of interest in optimistic belief updating (Consumers vs. Doubters (U = 2,734, P = 0.41); Knowers vs. Duffers ($t_{(27)}$ = 0.42, P = 0.68)), and in pessimistic belief updating [Consumers vs.Doubters (U = 2,683, P = 0.45); Knowers vs. Duffers (U = 76, P = 0.51)].

Psychological Self-Assessment Questionnaires
TIPI
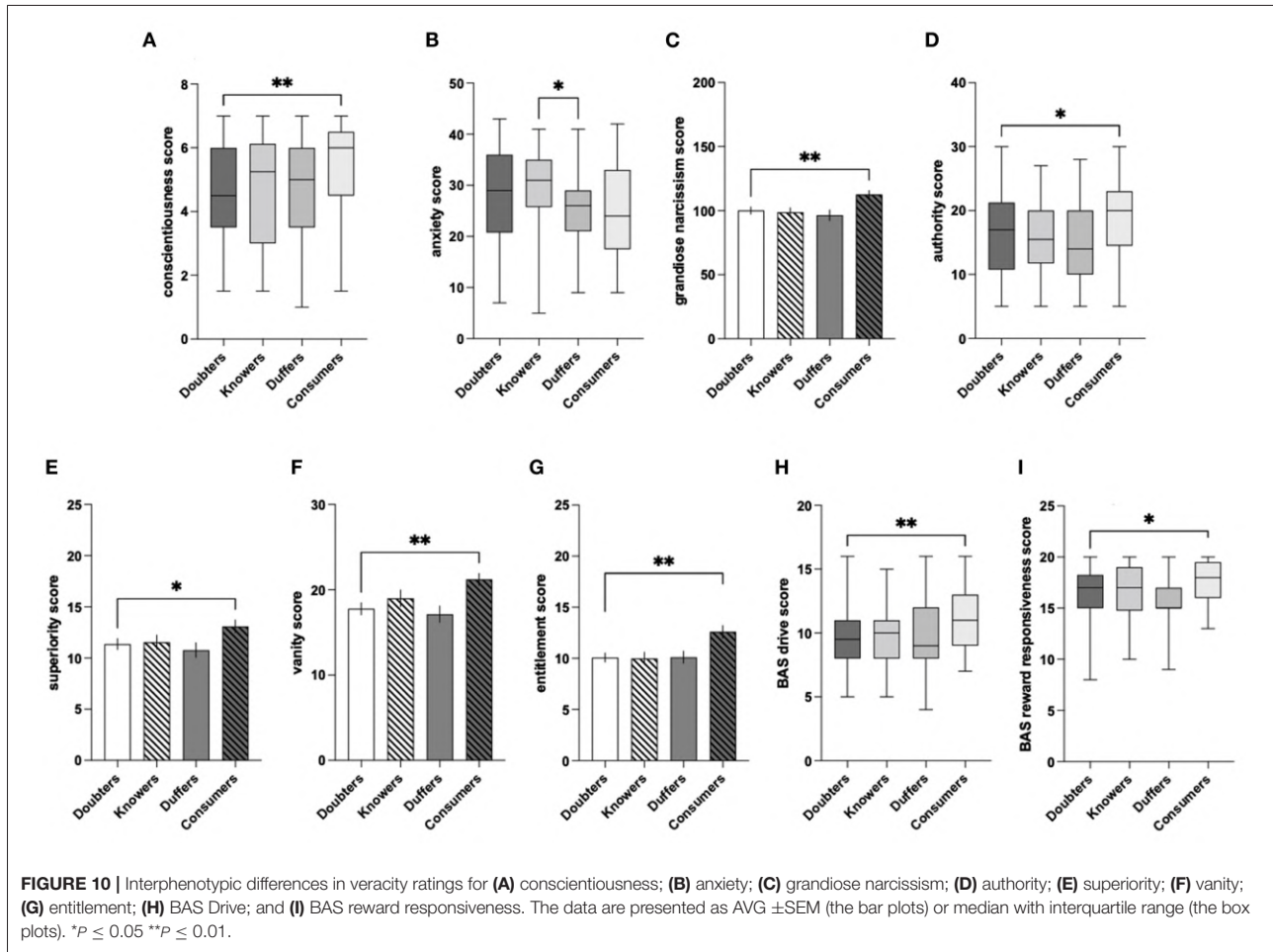The analysis of the 5-factor model from TIPI revealed that, compared to Doubters, Consumers were more extraverted (U = 2,356, P = 0.02; **Figure 11E**), more conscientious (U = 2,411, P = 0.03; **Figure 11F**), and more emotionally stable (U = 2,449, P = 0.046, **Figure 11G**). There was no significant difference between Doubters and Consumers in agreeableness (U = 2,553, P = 0.10) and openness to experience (U = 2,950, P = 0.85).

In the case of agreeableness, Duffers scored higher than Knowers [$t_{(27)}$ = 3.31, P = 0.003; **Figure 11H**]. However, the analysis revealed no significant differences between these phenotypes in extraversion [$t_{(27)}$ = 0.44, P = 0.66], conscientiousness (U = 77.5, P = 0.24), emotional stability [$t_{(27)}$ = 0.15, P = 0.87], and openness to experience (U = 68, P = 0.11).

TAS
The TAS analysis revealed that Doubters were more anxious than Consumers [$t_{(153)}$ = 2.31, P = 0.02; **Figure 11I**]. There was no significant difference between Knowers and Duffers [$t_{(27)}$ = 0.77, P = 0.45].

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FIGURE 10 | Interphenotypic differences in veracity ratings for **(A)** conscientiousness; **(B)** anxiety; **(C)** grandiose narcissism; **(D)** authority; **(E)** superiority; **(F)** vanity; **(G)** entitlement; **(H)** BAS Drive; and **(I)** BAS reward responsiveness. The data are presented as AVG ±SEM (the bar plots) or median with interquartile range (the box plots). *$P \leq 0.05$ **$P \leq 0.01$.

GNS

The analysis of GNS revealed that the Consumers had higher scores than Doubters in grandiose narcissism [$t_{(153)} = 3.14$, P = 0.002; **Figure 11J**], authority (U = 2,397, P = 0.03; **Figure 11K**), superiority [$t_{(153)} = 2.18$, P = 0.03; **Figure 11L**], vanity [$t_{(153)} = 3.31$, P = 0.001; **Figure 11M**], and entitlement [$t_{(153)} = 4.23$, P < 0.001; **Figure 11N**]. There were no significant differences between Doubters and Consumers in self-sufficiency (U = 2,717, P = 0.31), exploitativeness (U = 2,581, P = 0.13), or exhibitionism (U = 2,672, P = 0.24). The analysis revealed no significant differences between Knowers and Duffers in grandiose narcissism [$t_{(27)} = 0.25$, P = 0.81], authority [$t_{(27)} = 0.54$, P = 0.60], superiority [$t_{(27)} = 0.71$, P = 0.49], vanity [$t_{(27)} = 0.75$, P = 0.46], entitlement (U = 96.5, P = 0.72), self-sufficiency [$t_{(27)} = 0.27$, P = 0.79], exploitativeness (U = 103, P = 0.94), and exhibitionism [$t_{(27)} = 0.25$, P = 0.81].
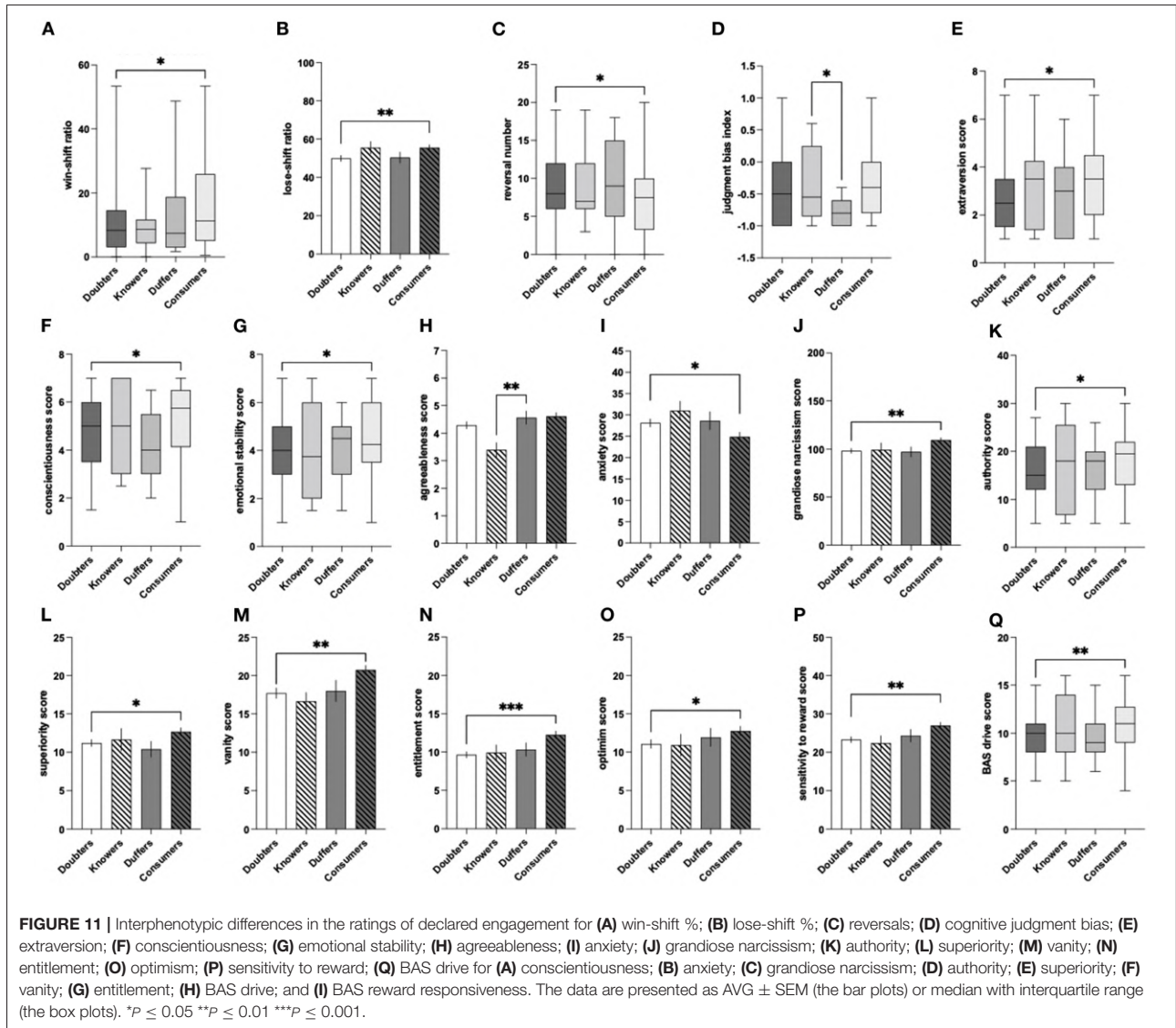
LOT-R

The analysis of LOT-R revealed that Consumers were more optimistic than Doubters [$t_{(153)} = 2.09$, P = 0.040; **Figure 11O**]. No significant differences were found between Knowers and Duffers [$t_{(153)} = 0.55$, P = 0.59].

BIS/BAS Scale

The analysis of variables from the BIS/BAS scale revealed that Consumers scored significantly higher than Doubters in BAS drive (U = 2,102, P = 0.001; **Figure 11Q**). There were no significant differences between these two phenotypes in BAS fun seeking (U = 2,781, P = 0.43), BAS reward responsiveness (U = 2,681, P = 0.25), or BIS (U = 2,541, P = 0.10). Knowers and Duffers did not significantly differ in any of these parameters—BAS Drive [$t_{(27)} = 1.01$; P = 0.32], BAS fun seeking [$t_{(27)} = 0.51$, P = 0.62], BAS Reward Responsiveness (U = 99, P = 0.81), and BIS (U = 104, P = 0.97).

SPSRQ-RC

The analysis of SPSRQ-RC revealed that Consumers were more sensitive to reward than Doubters $t_{(153)} = 3.25$, P = 0.001; **Figure 11P**). There was no significant difference between these phenotypes in sensitivity to punishment (U = 2,682, P = 0.25). No significant differences were revealed between Knowers and Duffers in sensitivity to reward [$t_{(27)} = 0.77$, P = 0.45] and sensitivity to punishment [$t_{(27)} = 1.1$, P = 0.28].

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FIGURE 11 | Interphenotypic differences in the ratings of declared engagement for **(A)** win-shift %; **(B)** lose-shift %; **(C)** reversals; **(D)** cognitive judgment bias; **(E)** extraversion; **(F)** conscientiousness; **(G)** emotional stability; **(H)** agreeableness; **(I)** anxiety; **(J)** grandiose narcissism; **(K)** authority; **(L)** superiority; **(M)** vanity; **(N)** entitlement; **(O)** optimism; **(P)** sensitivity to reward; **(Q)** BAS drive for **(A)** conscientiousness; **(B)** anxiety; **(C)** grandiose narcissism; **(D)** authority; **(E)** superiority; **(F)** vanity; **(G)** entitlement; **(H)** BAS drive; and **(I)** BAS reward responsiveness. The data are presented as AVG ± SEM (the bar plots) or median with interquartile range (the box plots). *$P \leq 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$.

DISCUSSION

The present study proposed the concept of four phenotypes of susceptibility to (mis)information that result from combining individual veracity ratings of true and fake news and similar classification based on behavioral engagement with true and fake news. Empirical implementation of this concept provides a holistic approach to the investigation of the susceptibility to (mis)information that had not previously been operationalized in the fake news research. The results of our study also revealed that phenotypes of susceptibility to (mis)information differed with respect to several cognitive processes and psychological traits. Both ways of phenotypic classification, which were established on the basis of the veracity ratings and the one established on the basis of engagement with the news ratings, revealed statistically

significant interphenotypic differences in psychological traits, including conscientiousness, anxiety, narcissism, and BAS drive. The phenotypes based on engagement with the news differed from each other in extraversion, agreeableness, emotional stability, dispositional optimism, and sensitivity to reward. Moreover, they also differed in several cognitive processes, including sensitivity to positive and negative feedback measured in the PRL tests and cognitive judgment bias measured in the ACI paradigm.

When analyzing factors altering susceptibility to misinformation, it is important to consider not only the extent to which misinformation is believed in relation to true content (truth discernment) but also the overall degree to which information is believed, regardless of its truthfulness. This is important because although increasing or decreasing belief

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in true and false headlines to an equivalent extent does not affect truth discernment, it might still determine the effects of misinformation (7). To address this need, in our study, we introduced the innovative concept of four phenotypes of susceptibility to (mis)information that result from combining individual veracity ratings and/or engagement with true as well as false news. The resulting phenotypes of Doubters, Duffers, Knowers, and Consumers encompass four combinations of susceptibility to (mis)information allowing for a complex and holistic analysis of factors influencing susceptibility to misinformation itself and its position within the spectrum. The analysis of phenotypes' frequency distribution revealed that contrary to Duffers and Knowers, the most numerous phenotypes were Doubters and Consumers. While the higher frequency of phenotypic Doubters and Consumers vs. Knowers and Duffers, distinguished based on the engagement with information, seems intuitive—some people willingly share content and others rarely engage in any social media activity, the disproportion in the frequency of phenotypes distinguished based on veracity judgments was surprising. A possible explanation implies the "all-or-nothing" bias (35), which is a tendency to dichotomously perceive reality that drives people to choose extremes. In the case of the present study, the majority of the participants rated all news as true (Consumers) or all news as false (Doubters).

In the present study, the interphenotypic differences in cognitive and psychological traits were analyzed along two different axes: one encompassing a general susceptibility/unsusceptibility to information (Consumers vs. Doubters), and the other that differentiated people who were susceptible to fake news from those who were unsusceptible to this type of information (Knowers vs. Duffers). Importantly, they were analyzed not only on the level of basic veracity ratings but also in terms of behavioral engagement (liking, sharing). Performed analyses revealed (**Figure 12**) that the people highly rating the veracity of all incoming information (Consumers), compared to those who were less likely to believe any information (Doubters), could be described as highly motivated, authoritarian, vain narcissists with a sense of superiority and entitlement who are highly responsive to a reward. The higher levels of narcissism, vanity, sense of entitlement, and superiority also characterized Consumers classified in terms of behavioral engagement. People displaying this phenotype were more emotionally stable and optimistic than Doubters. Notably, high engagement with all sorts of news was characterized by decreased anxiety and volatility in using feedback to guide decisions about future actions, as indicated by higher levels of win-shift and lose-shift behaviors in the PRL task. The latter suggests that despite being sensitive to rewards, Consumers are unconcerned with the feedback of their actions. This might be explained by higher emotional stability and a lower level of dispositional anxiety, accompanied by optimism, which prevent Consumers from experiencing negative emotions connected to unflattering opinions of others, for example, on social media. In contrast, higher anxiety, lower emotional stability, and lower dispositional optimism may be responsible for the lack of behavioral engagement with the news by Doubters.

It is worth noting that Consumers, in terms of both veracity rating and engagement with the news, also demonstrated significantly higher conscientiousness than Doubters. This observation suggests that Consumers might require more time and evidence to classify news as false and prefer to engage with any sort of information for further exploration.

Analysis of the second axis of vulnerability to the news, e.g., susceptibility to true vs. fake news, revealed that Duffers, distinguished based on their veracity judgments, were less anxious than Knowers. Two possible explanations might be considered. From one perspective, the existence of the pandemic is threatening, and people who deny the true information about it do so because they do not perceive it as dangerous enough to believe it. Another perspective suggests that Knowers who accept the danger of the pandemic are more anxious because of the threat behind it, whereas Duffers might find fake news anxiolytic. Whether low anxiety causes believing in false information or false information lowers anxiety is difficult to determine based on the results of this study, and the discussed causation should be further explored in future experiments.

The exploration of differences between Knowers and Duffers distinguished based on engagement with true and false information revealed that Duffers were more pessimistically skewed in interpreting ambiguous cues. This observation could explain why these people prefer to share and like false information, which often presents conspiracies that generally accuse some third persons or institutions to have malicious intentions. Engagement with fake news seems to escalate together with increased agreeableness. Indeed, while in the information bubble, persons who are more agreeable might be more likely to engage with fake news than others.

The empirical results reported herein should be considered in light of some limitations. Since social media constitute the natural environment where individuals interact with (mis)information, we designed our scale of susceptibility to (mis)information in a way that mimicked Facebook headlines. This approach, although broadly used in similar research, could be improved by conducting more ecological, real-time studies using algorithms tracking the behavior of users on social media platforms. This would help to eliminate situations where declared willingness to share or like given information in a survey might differ from actual sharing and liking behavior in social media. The second possible limitation might concern the online data collection and lack of control over the setting in which participants provided their responses, e.g., the PRL or ACI tests have never been previously used in the studies conducted online. This, however, has been mitigated by recruiting experienced but not professional individuals (see Methods) and performing attentional checks, which warranted motivation and devotion of the study participants.

CONCLUSION

Our findings indicated the presence of various phenotypes of susceptibility to (mis)information, characterized by

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FIGURE 12 | Psychological profiles of the phenotypes of susceptibility to (mis)information.
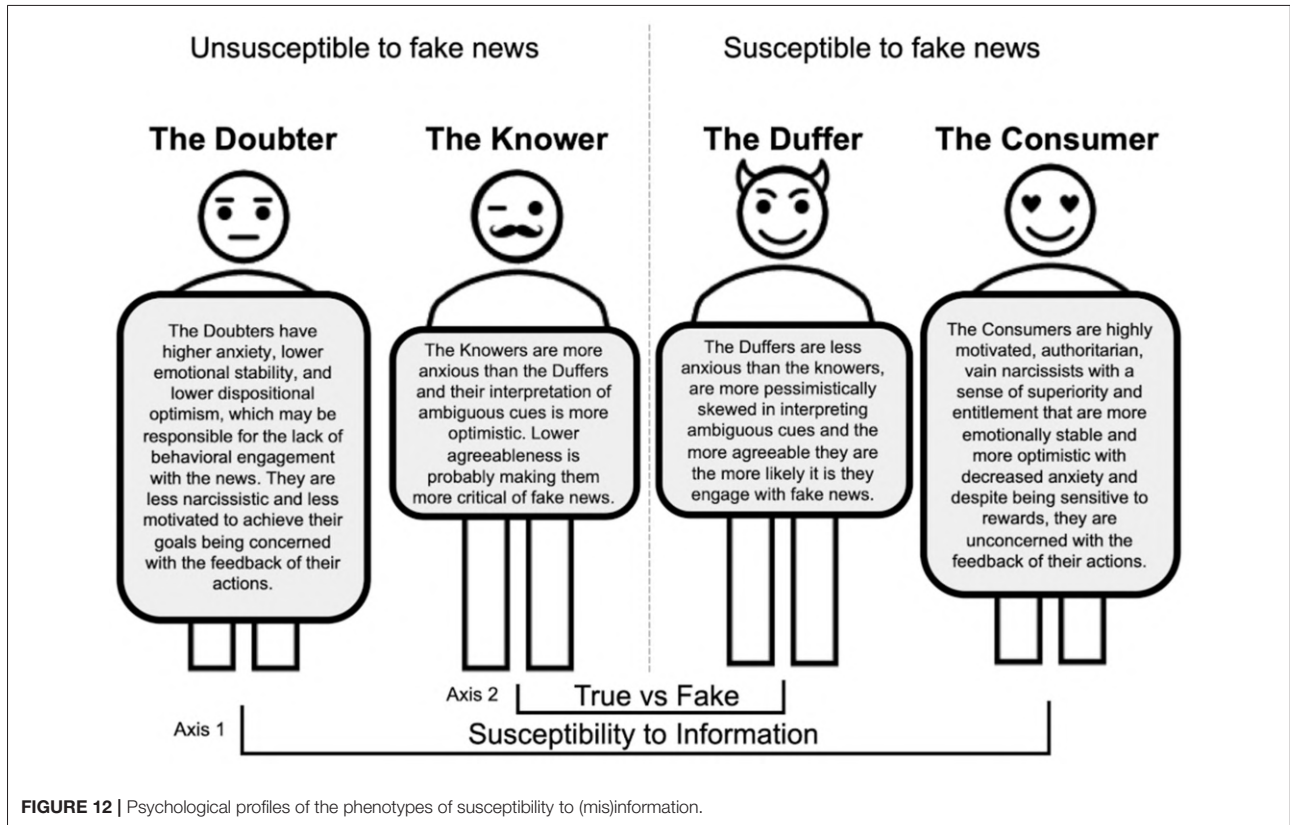
different clusters of cognitive and psychological traits. They also indicated that the concept of vulnerability to fake news cannot be investigated in isolation from the general susceptibility to information regardless of its veracity. Outlining the four phenotypes of susceptibility to (mis)information creates foundations for further research that should focus on the real-time behavior of people using social media and on the diagnosis of vulnerability to misinformation.

DATA AVAILABILITY STATEMENT

All data analyzed in this study have been made publicly available via Jagiellonian University Repository (33), and can be accessed here: https://ruj.uj.edu.pl/xmlui/handle/item/289808? locale-attribute=en.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Bioethics Committee of Jagiellonian University in Krakow, Poland (1072.6120.66.2021 from 19 May 2021). The

patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JP, JK, and RR obtained funding. MP, KN, AG, JP, JK, and RR designed and planned the research. MP conducted the experiment and analyzed the data. MP and RR wrote the manuscript. MP, KN, JP, PG, AG, JK, and RR revised the the manuscript and contributed to the final discussion. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt. 2022.912397/full#supplementary-material

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Research Report: A Link between Sertraline Treatment and Susceptibility to (Mis)information

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ABSTRACT: Recent research revealed that several psycho-cognitive processes, such as insensitivity to positive and negative feedback, cognitive rigidity, pessimistic judgment bias, and anxiety, are involved in susceptibility to fake news. All of these processes have been previously associated with depressive disorder and are sensitive to serotoninergic manipulations. In the current study, a link between chronic treatment with the selective serotonin reuptake inhibitor (SSRI) sertraline and susceptibility to true and fake news was examined. Herein, a sample of 1162 participants was recruited via Prolific Academic for an online study. Half of the sample reported taking sertraline (Zoloft) for at least 8 weeks (sertraline group), and the other half confirmed not taking any psychiatric medication (control group). The sertraline group was further divided according to their daily dosage (50, 100, 150, and 200 mg/day). All participants completed a susceptibility to misinformation scale, wherein they were asked to determine the veracity of the presented true and fake news and their willingness to behaviorally engage with the news. The results were compared between those of the sertraline groups and the control group. The results showed that sertraline groups did not differ significantly in the assessment of the truthfulness of information or their ability to discern the truth. However, those taking sertraline appeared to have a significantly increased likelihood of behavioral engagement with the information, and this effect was observed for both true and fake news. The research presented here represents the initial endeavor to comprehend the neurochemical foundation of the susceptibility to misinformation. The association between sertraline treatment and increased behavioral engagement with information observed in this study can be explained in light of previous studies showing positive correlations between serotonin (5-HT) system activity and the inclination to engage in social behaviors. It can also be attributed to the anxiolytic effects of sertraline treatment, which mitigate the fear of social judgment. The heightened behavioral engagement with information in people taking sertraline may, as part of a general phenomenon, also shape their interactions with fake news. Future longitudinal studies should reveal the specificity and exact causality of these interactions.
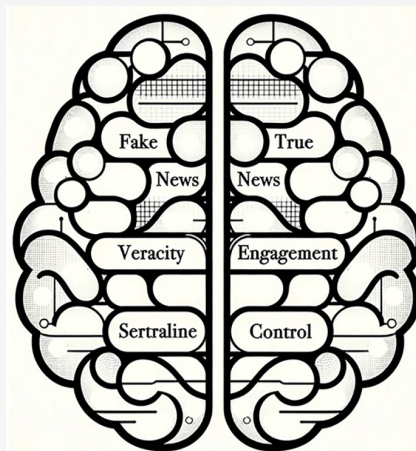
KEYWORDS: Misinformation, sertraline, susceptibility to fake news, serotonin, online research

INTRODUCTION

From ancient Egypt up to the present day, information that is not true or is meant to be misleading has been used to make money, change people's views and opinions, and make them question who they can trust.[1] With the emergence of the Internet and social media, people acquired more sophisticated techniques for spreading false (fake) news, which seems to be everywhere and travels faster than at any other point in history.[2] At a time when misinformation can be easily promoted and shared, it is important to understand what makes people susceptible to believing and sharing fake news. Developing effective interventions against misinformation depends not only on understanding the underlying psychology but also on elucidating the neuronal and neurochemical

mechanisms of susceptibility to fake news.[3−7] Indeed, in the past few years, the phenomenon of misinformation has received increasing attention from psychologists, neurobiologists, and cognitive scientists who have examined personality traits and cognitive processes involved in susceptibility to misinformation.[8,9]

A

Recent research revealed that insensitivity to positive and negative feedback, lowered cognitive flexibility, pessimistic judgment bias, and anxiety are critically involved in fake news susceptibility.[9]

Interestingly, at the neurobiological level, all of the above-mentioned cognitive functions and personality traits are modulated by 5-HT neurotransmission. For example, decreasing 5-HT levels in the central nervous system by acute tryptophan depletion (ATD) results in increased sensitivity to negative feedback.[10,11] Similar effects were observed following the administration of a low, acute dose of the selective serotonin reuptake inhibitor (SSRI) citalopram, which was postulated to paradoxically decrease 5-HT levels by inhibiting presynaptic autoreceptors.[12]

SSRIs have also been demonstrated to enhance cognitive flexibility. Acute treatment with the (S)-stereoisomer of citalopram, i.e., escitalopram, improved shifting away from prelearned behavioral patterns in rats,[13] while Brigman and colleagues[14] provided evidence that chronic administration of another SSRI, fluoxetine, significantly increased cognitive flexibility in the probabilistic reversal learning (PRL) test.

SSRIs have also been proven to modify cognitive judgment bias. In a study from 2014, Rygula and colleagues[15] showed that an acute, low dose of citalopram caused a pessimistic interpretation of ambiguous cues, whereas a high dose shifted this bias toward an optimistic interpretation. Other studies demonstrated that chronic administration of fluoxetine had pro-optimistic effects on rats.[16,17]

Finally, extensive research has revealed that alterations in the 5-HT system are involved in anxiety disorders. Van der Wee and colleagues[18] demonstrated higher binding potentials for the serotonin transporter as well as a reduced number of serotonin 5-HT1A receptors in the thalamus of patients with generalized social anxiety disorder (gSAD). In another study, patients diagnosed with gSAD who were successfully treated with SSRIs and underwent an ATD showed a significantly larger salivary alpha-amylase response to a public speaking task than the placebo group.[19] SSRIs such as escitalopram, paroxetine, and sertraline have also been reported to be the first-choice treatment for different anxiety disorders.[20]

It is also important to note that the behavioral aspect of susceptibility to true and fake information, which manifests on social media as one's willingness to like, share, comment, upvote, and retweet, can be understood as a manifestation of social behaviors, similar to a real-life conversation, social approval, and gossiping.[21,22] Interestingly, decades of research have linked 5-HT to prosocial behavior, indicating that 5-HT not only mediates trait-like individual differences in sociability but also causally modifies dynamic changes in prosocial tendencies. In an early study, Raleigh and colleagues demonstrated that enhancing 5-HT function decreased aggression and increased social approach and grooming in vervet monkeys.[23] In turn, low or impaired 5-HT function has been associated with social isolation and aggression.[23−25] Further studies in humans supported these observations by showing that manipulating the 5-HT function influences cooperation and social dominance. In the study by Moskowitz, tryptophan supplementation decreased quarrelsome behaviors in tryptophane-depleted volunteers,[24] while in the study by Knutson and colleagues, treating healthy volunteers with the 5-HT-enhancing drug SSRI paroxetine increased affiliative and cooperative behaviors during a group-based problem-solving task.[26] Two other studies using the SSRI citalopram also

observed increased dominant behaviors, cooperative communication, and cooperative play during a prisoner's dilemma game.[27,28] The prosocial role of 5-HT is further underscored by the profound prosocial effects of the recreational drug 3,4-methylenedioxymethamphetamine (MDMA, Ecstasy), which induces a substantial release of 5-HT.[25]

Given these extensive examples of serotoninergic modulation in the mentioned psycho-cognitive processes and the involvement of the latter in susceptibility to information,[9] in the current study, a possible link between a chronic treatment with the SSRI sertraline and susceptibility to true and fake news was examined.

For this, a sample of 1162 participants was recruited for an online study. Half of the sample reported taking sertraline (Zoloft) for at least 8 weeks, and the other half confirmed not taking any psychiatric medication. The sertraline group was further divided according to the daily dosage. All participants completed a susceptibility to misinformation scale[9] wherein they were asked to determine the veracity of the presented true and fake news and their willingness to behaviorally engage with it. The results were compared between the sertraline and nonsertraline groups.

■ RESULTS AND DISCUSSION

Participants. Initially, the goal was to recruit 1000 participants being treated with sertraline (SG) and 1000 participants who did not take any psychiatric medication (CG). However, due to a prolonged time to reach these sample sizes, after 2 months recruitment was stopped at 866 participants taking sertraline and 1000 control participants.

Among SG, 581 participants fulfilled the criteria described in the Methods section. To match this sample size, the first 581 participants from the CG were included for further analyses. In the next step, the SG was divided into 4 subgroups according to the declared daily dose of sertraline: 50 mg/day ($N = 214$), 100 mg/day ($N = 212$), 150 mg/day ($N = 93$), and 200 mg/day ($N = 62$). Table 1 presents the detailed composition of CG and SGs with respect to the age and gender of the subjects.

Table 1. Detailed Composition of Control and Sertraline Groups with Respect to the Participants' Ages and Genders

Group	Age, mean (SD)	Participants, n	Gender, n		
			Female	Male	Nonbinary
General	36.5 (12.9)	1162	819	328	15
Control Group	39.5 (14.3)	581	352	225	4
Sertraline Group	33.9 (9.6)	581	467	103	11
50 mg	31.9 (9.6)	214	180	30	4
100 mg	33.5 (10.3)	212	170	37	5
150 mg	36.0 (11.6)	93	72	21	0
200 mg	35.7 (10.6)	62	45	15	2

Analysis of gender effects on measured parameters [veracity rating of fake news ($H_{(2)} = 6.348$, $p = 0.042$; nonbinary−male ($p = 0.999$), nonbinary−female ($p = 0.487$), male−female ($p = 0.085$)), veracity rating of true news ($H_{(2)} = 4.996$, $p = 0.082$); veracity discernment index ($H_{(2)} = 2.342$, $p = 0.31$), behavioral engagement with fake news ($H_{(2)} = 8.78$, $p = 0.012$; nonbinary−male ($p = 0.327$), nonbinary−female ($p = 0.091$), male−female ($p = 0.09$)), behavioral engagement
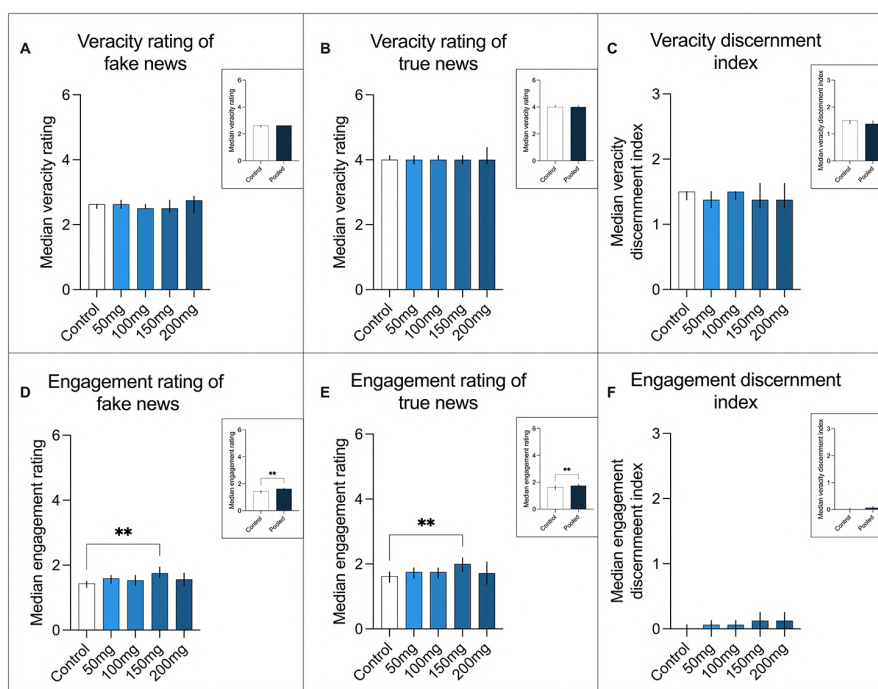
Figure 1. Chronic sertraline treatment and susceptibility to fake news and true news. The control and sertraline groups (50, 100, 150, and 200 mg/day for at least 8 weeks) did not significantly differ in the median veracity rating of fake news (A), median veracity rating of true news (B), or median veracity discernment index (C). There was also no significant difference on veracity when the data from all tested doses were pooled (insets in Panels A, B, and C). Behavioral engagement with fake news (D) and behavioral engagement with true news (E) were significantly higher in the sertraline group taking a dose of 150 mg/day than in the control group. A significant difference on engagement was also observed when the data from all tested doses were pooled (insets in Panels D and E). Sertraline groups did not significantly differ on the behavioral engagement discernment index (F and F inset). The data are presented as the median $\pm$ 95% confidence intervals; ** $P <.01$.

with true news ($H_{(2)}$ = 7.91, p = 0.019; nonbinary−male (p = 0.567), nonbinary−female (p = 0.178), male−female (p = 0.08)), and behavioral engagement discernment index ($H_{(2)}$ = 0.075, p = 0.963)] revealed no statistically significant differences between genders.

There was no statistically significant correlation between the age of participants and veracity rating of fake news (rho = −0.054, P = 0.064), veracity rating of true news (rho = 0.007, P = 0.808), behavioral engagement with fake news (rho = −0.012, P = 0.681), behavioral engagement with true news (rho = −0.004, P = 0.808), and behavioral engagement discernment (rho = 0.021, P = 0.808). Age only correlated very weakly with the veracity discernment index (rho = 0.058, P = 0.049). Therefore, age is not considered to be a confounding factor in this study.

Principal Findings. The CG and SG (50, 100, 150, and 200 mg/day for at least 8 weeks) did not significantly differ in the median veracity rating of fake news ($H_{(4)}$ = 4.06, P = 0.40; Figure 1A), median veracity rating of true news ($H_{(4)}$ = 4.53, P = 0.34; Figure 1B), or median veracity discernment index ($H_{(4)}$ = 4.12, P = 0.39; Figure 1C). A comparison of the data from the CG and pooled data from all SG also revealed no significant differences on the median veracity rating of the fake news (U = 164009, P = 0.40; Figure 1A inset), true news (U = 166449, P = 0.68; Figure 1B inset), and veracity discernment index (U = 163156, P = 0.33; Figure 1C inset).

Analysis of the behavioral engagement data revealed significantly (P = 0.003) higher ratings of behavioral engagement with fake news (Figure 1D) and significantly (P = 0.008) higher ratings of behavioral engagement with true

news (Figure 1E) in the SG at a dose of 150 mg/day than in the CG ($H_{(4)}$ = 14.9, P = 0.005 and $H_{(4)}$ = 11.9, P = 0.018 respectively).

The Mann−Whitney U test confirmed a significant difference between pooled SG and CG in engagement with fake news (U = 150505, P = 0.001; Figure 1D inset) and a significant difference between pooled SG and CG in engagement with true news (U = 153365, P = 0.007, Figure 1E inset).

The sertraline groups did not significantly differ from the CG in the behavioral engagement discernment index either when compared for each dose separately ($H_{(4)}$ = 2.93, P = 0.57; Figure 1F) or when pooled (U = 167578, P = 0.83; Figure 1F inset).

In this study, a link between the pharmacological modulation of the serotonergic system and sensitivity to information in humans was examined. The results of the conducted experiment showed that chronic treatment with SSRI sertraline was not associated with altered assessment of the truthfulness of information or the ability to discern the truth. Sertraline treatment, however, was linked with an increased declared behavioral engagement with the information, and this effect was observed for both true and fake news.

Comparison to Prior Work. The association between the pharmacologically enhanced 5-HT function and behavioral engagement observed in this study can be explained in light of previous studies linking the activity of the 5-HT system to social behaviors. Indeed, decades of research have linked 5-HT to social activities and demonstrated that 5-HT not only influences trait-like individual differences in social behavior[26]

but also causally drives dynamic state changes in social tendencies.[27,28] Low or impaired 5-HT function has been associated with social isolation and aggression, while high or enhanced 5-HT function has been connected with social dominance, affiliation, and prosocial tendencies.[23−25] On social media, behaviors such as sharing posts and reacting to them with likes or comments can be interpreted as analogues of real-life social behaviors; thus, the engagement-enhancing effects of 5-HT booster-sertraline are not surprising.

The anxiolytic properties of sertraline[20] may also explain the differences observed in this study. Indeed, behavioral engagement with the news on social media might evoke social anxiety,[29] especially when the topic is socially polarizing, e.g., the COVID-19 pandemic.[30] From this perspective, the increased declared engagement with the news would index the anxiolytic effects of sertraline, which vanquishes the fear of social judgment.

Although the potential behavioral engagement-enhancing effect of sertraline was common to all subjects taking the drug, a dose-by-dose analysis showed that a statistically significant effect occurred only at the dose of 150 mg/day and was absent in people taking lower (50 and 100 mg/day) and higher (200 mg/day) doses. This observation was not surprising, since several previous studies have demonstrated that sertraline has an inverted U-shaped dose−response curve in humans (for a review, see ref 31). Indeed, doses below or at the lower end of the recommended dose range (50−200 mg) were reported to have inferior effectivity,[32] while a large randomized controlled trial that compared sertraline at 50, 100, and 200 mg/day in major depression demonstrated that higher doses added no therapeutic benefits but doubled the rate of side effects such as agitation, insomnia, sedation, and nausea.[33]

Strengths and Limitations. Despite the best efforts, the study described here has certain limitations that warrant discussion. Foremost among these limitations is the inability to establish a causal relationship between sertraline intake and susceptibility to engaging behaviorally with information.

As an observational investigation, the study relied on data collected from individuals undergoing pharmacological modulation of the serotonergic system and those not undergoing such treatment. This design permits inferences about potential disparities in engagement with true and fake news only between individuals taking 150 mg/day of sertraline and those not taking sertraline. However, the precise causes of these differences remain unknown and necessitate further investigation. Although it can be assumed that participants were prescribed sertraline for affective or anxiety disorders, the specific diagnoses are unknown as they could not be verified in a nonclinical sample. To establish a causal relationship, future research should employ longitudinal experimental designs. Such an approach could provide a more comprehensive understanding of the interconnections among the serotonergic system, information processing, and susceptibility to (mis)-information.

Another limitation of the current study is that it did not control for many socio-economic and psychological factors such as, e.g., political orientation, cognitive biases, or psychological traits, that can impact susceptibility to misinformation. There were so many potential factors that attempting to control them would be nearly impossible. This study is intended as a preliminary step in testing the hypothesis that there is the potential for pharmacological intervention to

affect information sensitivity. Undoubtedly, more comprehensive research is required to provide a definitive answer.

Second, it is important to underline that the present study used an online methodology, which thus far is atypical in the field of psychopharmacology, that provides, however, a plethora of benefits known in social sciences, e.g., a large sample collected in a relatively short time, low experimental costs, and small ethical dilemmas.[34] An intriguing question concerns, however, how reliable the treatment details declared by participants are and how these would compare to laboratory-based studies. Additionally, because participation in the study required prior experience with online tests, the possibility that prior exposure to similar tests may have influenced the results, to some extent, cannot be dismissed. However, this appears improbable, as this criterion ensures proficiency in navigating the Prolific platform rather than expertise in identifying fake news.

Third, another important limitation lies in the method used to assess misinformation susceptibility. The present study relied on a questionnaire to measure individuals' vulnerability to (mis)information. While questionnaires are valuable tools for gathering self-reported data,[35] it is crucial to acknowledge that people's responses might not perfectly align with their real-world behaviors when confronted with misinformation in practical scenarios, e.g., social media. Social desirability bias[36] or subjective interpretations of the questions could potentially influence the results, leading to a discrepancy between reported susceptibility and actual behavior.[37]

Fourth, the question presented in the applied questionnaire, "Do you think the news above is true?" could be perceived as a leading question, potentially predisposing participants to offer biased answers. It is possible that querying participants with "Do you think the news above is fake?" might have yielded slightly different responses. In hindsight, adopting a more neutral phrasing such as "Please rate the veracity of the news above" appears to provide a more effective solution. Likewise, the truthfulness discrimination index employed here, characterized as the distinction between ratings for true and false news, is susceptible to potential confounding factors and response bias. This includes the inclination to rate all news items uniformly. Nevertheless, analogous questionnaire-based methodologies for investigating susceptibility to misinformation find widespread application in other research endeavors.[38−41]

Fifth, the differences in the magnitude of computed Cronbach's alpha coefficients for the veracity ratings (α = 0.59 for true items, α = 0.62 for fake items) and behavioral engagement ratings (α = 0.94 for true items, α = 0.90 for fake items) can be considered as another limitation of the present study. While this could imply that the scales might capture multiple dimensions of misinformation susceptibility, some of which could potentially be generalized to other domains, it also raises considerations about the scales' internal consistency (reliability) in assessing a singular construct of misinformation susceptibility. Given that the sole variations in the outcomes pertained to the engagement ratings, where high alphas were recorded, the inquiry arises as to whether comparable findings would have been noted for veracity ratings had the veracity scales exhibited more robust reliability.

Sixth, another noteworthy limitation of this study pertains to the considerable variation in sample sizes across the four sertraline dosage groups. Specifically, the participant distribution in the dosage groups was as follows: 50 mg/day (n = 214),
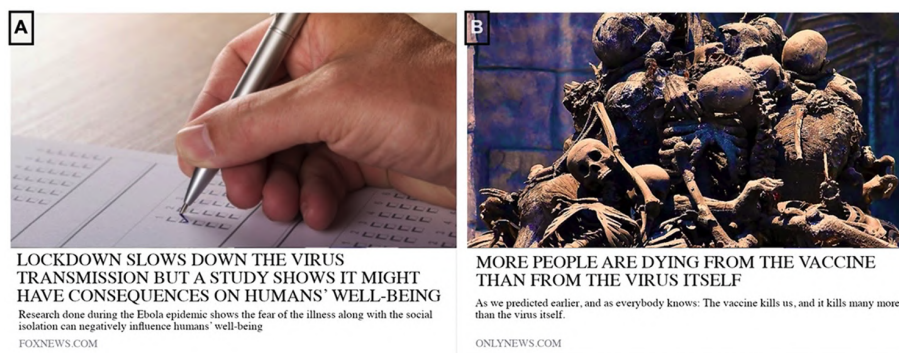
Figure 2. Examples of news items: Panel A — True news. Panel B — Fake news.

100 mg/day (n = 212), 150 mg/day (n = 93), and 200 mg/day (n = 62). This uneven distribution introduces a potential source of bias and might impact the statistical power and precision of the findings. However, the analysis was conducted using the nonparametric Kruskal–Wallis test, which is relatively resilient to uneven sample distributions.[42] Future studies could benefit from more equal and larger sample sizes to enhance the robustness and generalizability of the findings across different dosage groups.

Lastly, it is noteworthy that the scope of the misinformation susceptibility scale employed in this study was restricted solely to Covid-19 pandemic-related information. This limitation could potentially curtail its relevance in evaluating the overall susceptibility to misinformation across other contexts or subjects.

■ CONCLUSION

The research presented in this article represents the initial endeavor to comprehend the neurochemical foundation of susceptibility to misinformation. This susceptibility can be defined not only as the capacity to differentiate between truth and falsehood but also as a predisposition to participate in the dissemination of a particular piece of information. An analysis of the differences between individuals treated with sertraline, a drug that enhances brain serotonin levels, and those who did not take the drug revealed that although sertraline treatment is not associated with the ability to discern truth from falsehood, it is linked with the willingness to behaviorally engage with information and, by the same token, with its increased propagation.

The association between sertraline treatment and increased behavioral engagement with information observed in this study can be explained in the light of previous studies showing positive correlations between 5-HT system activity and the inclination to engage in social behaviors. It can also be accounted for by the anxiolytic effects of sertraline treatment, which vanquishes the fear of social judgment. The increased behavioral engagement with information in people taking sertraline may, as part of the general phenomenon, also define their engagement with fake news. Further, longitudinal studies are necessary to reveal the specificity and exact casual nature of these interactions.

The results presented here raise several intriguing and thought-provoking questions. First, what is the relationship between mental disorders such as anxiety and depression (for which sertraline is prescribed) and the susceptibility to misinformation? Second, can one's beliefs be manipulated pharmacologically, and third, can this previously unexplored effect of sertraline on the inclination to behaviorally engage in information be considered its side effect?

■ METHODS

Ethics Statement. This study was conducted in accordance with the guidelines laid down in the Declaration of Helsinki, and all procedures involving research study participants were approved by the Bioethics Committee of Jagiellonian University in Krakow, Poland (1072.6120.12.2022, from 26 January 2022). Informed consent was obtained from all participants. Moreover, participants were provided with a debriefing that disclosed which information was false and which was true.

Participants. The participants were recruited via Prolific Academic (prolific.com), a platform with a worldwide participants pool, that allows recruiting a specific sample, based on their prescreened characteristics. Two of the inclusion criteria were chosen—location (United Kingdom) and psychiatric medication use (sertraline for sertraline group (SG) and no medication for control group (CG)). The survey was automatically sent to Prolific users who matched these chosen criteria. During the survey, participants in the SG had to confirm taking sertraline for at least 8 weeks, report their daily dose, and affirm that they did not take any other psychiatric medication. As a nonclinical sample of participants was tested, their psychiatric diagnoses remain unknown. The participants in the CG had to confirm that they were not taking any psychiatric medication. Similar to previous research,[9] all of the participants had to pass two attention checks (the same command in two different locations: *You must pay attention to this study. Please tick "Somewhat agree"*), and all participants answered both checks correctly. To obtain reliable answers, only participants who had previously completed a minimum of 100 studies and a maximum of 500 studies, with an acceptance rate of ≥ 95% for the submitted surveys, were accepted for testing.

Procedure. The study was conducted between March 30th and May 29th, 2022. Eligible participants were recruited for the study via the online recruitment panel platform *Prolific Academic*. Following informed consent, they were redirected to the online testing platform *Qualtrics.com*, where they completed the survey. The survey consisted of demographic questions and statements on taking antidepressants and other psychiatric medications. Subsequently, the susceptibility to true and fake news was measured using a revised scale previously developed by Piksa et al.[9] In this scale, half of the items contained verifiable true information (Figure 2A) obtained from research reports and official World Health Organization guidelines and statistics.[43] The other half contained false information (Figure 2B) created by the research team. Both true and fake information were designed to look like news posted on Facebook. All of the items can be accessed in an online repository.[44]

Susceptibility to true and fake news was defined in two ways.[9] First, the participants were asked to evaluate each item in terms of its veracity ("*Do you think the news above is true?*") on a 6-point Likert scale (1 *definitely false* – 6 *definitely true*). Second, their behavioral

engagement with the news item was assessed by averaging participants' willingness to like the news item ("*On social media, I would give a "like" to this news*") and willingness to share the news item ("*I would share this news on my social media profile*"; 1 *totally disagree* − 6 *totally agree*). There was a positive correlation between the declared willingness to share the news item and the declared willingness to like the news item (for fake items: $r = 0.82$, $P < 0.001$; for true items: $r = 0.85$, $P < 0.001$).

By averaging the scores of all true and false news items, four variables emerged: true news veracity rating (Cronbach's $\alpha = 0.59$), false news veracity rating (Cronbach's $\alpha = 0.62$), engagement with true news rating (Cronbach's $\alpha = 0.94$), and engagement with false news rating (Cronbach's $\alpha = 0.90$). Two additional indices were calculated: the veracity discernment index, which was calculated by subtracting the false news veracity rating from the true news veracity rating, and the engagement discernment index, which was calculated by subtracting the false news engagement rating from the true news engagement rating. These indices represent participants' ability to discern true news from false news. A similar approach to truthfulness discernment was recently used by Maertens and colleagues.[38]

After completing the survey, the participants were informed of which news were true and which were fake and were compensated with 1.88 GBP.

Statistical Analysis. Data analysis was performed using SPSS (version 27.0, SPSS Inc., Chicago, IL, USA). The Shapiro−Wilk test was employed to assess the normality of the data distribution within the experimental groups. Given that the data significantly deviated from normality, nonparametric tests were applied for comparisons: the Kruskal−Wallis test with Dunn's post hoc adjustment was used to compare the control and sertraline groups, and the Mann−Whitney test was utilized for the pooled sertraline group data. The relationship between age and the parameters under investigation was examined using Spearman's correlation.

■ ASSOCIATED CONTENT

Data Availability Statement

All data analyzed in this study have been made publicly available via Jagiellonian University Repository[44] and can be accessed here: https://ruj.uj.edu.pl/xmlui/handle/item/304769

Ⓢ Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acschemneuro.3c00825.

Survey: Online Informed Consent for Participation in a Research Study(PDF)

Checklist for Reporting Results of Internet E-Surveys (CHERRIES) (PDF)

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■ ABBREVIATIONS

5-HT	Serotonin
ATD	Acute tryptophan depletion
CG	Control group
gSAD	Generalized social anxiety discorder
MDMA, Ecstasy	3,4-methylenedioxymethamphetamine
PRL	Probabilistic Reversal Learning (test)
SG	Sertraline taking group
SSRI	Selective serotonin reuptake inhibitor

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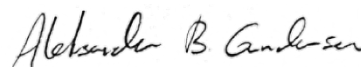
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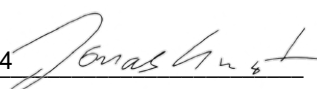
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* https://www.elsevier.com/researcher/author/policies-and-guidelines/credit-author-statement

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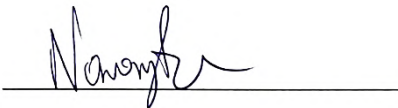
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