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Focus and Scope
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(or misused) as a part of belief systems underlying violent extremism (Rogers et al., 2007). Researchers disagree with the assertion that religion, per se, causes terrorism and that religion is more so used as a moral "excuse" for terrorist activity (Rogers et al., 2007). However, we should also consider the possibility that the faith healer Wail consulted was, in fact, a militant preacher who radicalized him at a time when he was emotionally vulnerable. Although, this is only speculative and, in all likelihood, there were numerous other bad actors who interacted with Wail during his radicalization.

Social Determinants of Radicalization

Wail and Walid al-Shehri were "muscle" hijackers on American Airlines Flight 11. The al-Shehri brothers were two of 11 children (Murphy & Ottaway, 2001). Both brothers studied at Abha Teacher Training College and attended the Seqeley mosque in Khamis Mushayt, a city inside Asir, Saudi Arabia. Wail was employed as an elementary school gym teacher, while his younger brother, Walid, was still in school studying to enter the same profession. Both brothers were single without children. Both were born in Asir. Asir is a southwestern province of Saudi Arabia described as a poor region, with weak policing and having a reputation as a "wild frontier" (National Commission on Terrorist Attacks upon the United States, 2004). This region was described by journalists as a conservative, tribal society with a high unemployment rate among young men (Lamb, 2002). In our case, however, the two brothers were educated and employed, which seems to indicate that other variables beyond socioeconomics played a more significant role in their radicalization.

Possible Sibling Effects

Given that the al-Shehri brothers were both willing to engage in violent terrorist activity, there might have been a sibling effect on such behavior. The older Wail may have influenced Walid into extremism due to the potential dominant and assertive traits often attributed to firstborn or older siblings, with later-born children often having more agreeable and submissive traits (Sulloway, 2001). In addition, a review of family studies suggested that antisocial and violent behavior is moderately heritable, indicating a possible genetic basis for violent extremism in particular (Poldrack et al., 2017; Anholt & Mackay, 2012).

Neurocognitive Development

While early life for the al-Shehri brothers was perhaps seemingly typical for young males in this region, it is important to recognize environmental factors that may have adversely impacted their brain development. These could have included limited resources for recreation, stimulation, or entertainment. Since little is known about their childhood, I can only assume a poverty of environmental stimuli as compared to my own western upbringing. People from Asir generally follow Wahhabist Islam, with the strict prohibition of cinema, theatre, dancing, drugs, and premarital relations between men and women (Lamb, 2002).

It has long been known that the environment plays a major role in neurodevelopment. Brain maturation is necessary but not sufficient for cognitive development. An enriched environment is also needed in order to afford the opportunities to practice and refine the skills associated with normal cognitive functioning (Kinsbourne & Caplan, 1979). An impoverished environment in Asir would not fully explain why the al-Shehri brothers engaged in terrorism. Yet, the brothers may have experienced a sense of relative loss. Their feelings of loss, experienced in the presence of limited opportunities for success, may have created feelings of frustration, humiliation, and victimization (Taspinar, 2009). These feelings may have later been linked to feelings of deprivation. Ultimately, radicalization may have filled their void and helped them to fulfill their desire to find meaning, but in a perverted fashion.

Radicalization

The al-Shehri brothers were reported to

have disappeared in 1999 while traveling to Medina, and upon their return home, their cousin described them as being different, having grown beards, increasingly religious, and associating with a secretive group of people. They were also described by this same cousin as being "ordinary guys" who later "changed" through some "kind of Islamic awakening." They also reportedly "heard sermons from people who came back from jihad in Afghanistan" (Lamb, 2002). These observations on personality changes and sudden intensification of ideological beliefs are indicative of radicalization. Social interactions with local community leaders, including militant preachers, likely influenced new patterns of thought and behavior in the al-Shehri brothers. Research shows "human behavior is influenced, directly and indirectly, by the presence and behavior of others. This is manifested in many phenomena studied by social psychology such as social influence, conformity, obedience, or compliance" (Decety et al., 2017, p. 6). In addition, Decety and colleagues reported that various brain regions have been implicated in social cognition, including the ventromedial prefrontal cortex (vmPFC), an area of the brain that is critically involved in social decision-making.

A closer study of how the al-Shehri brothers were radicalized may provide important insights and parallels to the Tsarnaev brothers, who were likewise radicalized and later involved in the Boston Bombings. However, important and insightful differences should emerge. The al-Shehri brothers were born and raised in a non-western environment, a relatively monocultural society, in the early stages of internet and computer technology, with lifetime exposure to conservative religion and traditional customs. In contrast, the Tsarnaev brothers lived most of their lives in a western environment, a multicultural society, in the later stages of internet and computer technology, with predominant exposure to moderate religion prior to radicalization. These are interesting differences that could help elucidate the various psychosocial trajectories into radicalization. However, such a comparison is beyond the scope of the current study.

Extant Literature: The Neuroscience of Terrorism

Mental Illness, Terrorism, and Neuroscience

One of the quintessential questions on the nature of terrorism is the potential role of mental illness. This is a contentious issue that has continued to generate discussion from opposing camps. Whenever we examine the brain basis of human behavior, especially violent extremist behaviors present in terrorism, there is often an underlying question: is the behavior being examined a result of an abnormality in the brain? While some researchers view the "terrorist mind" as essentially normal, others view it through the lens of psychopathology.

The kinds of psychological problems that may be present in terrorists fundamentally depends on whether they are a group or lone actors. For instance, recent research has raised the possibility of mental illness in some terrorist subgroups, such as lone actors (Corner, Gill, & Mason, 2016). In this study on lone-actor terrorists, researchers found a higher prevalence rate of schizophrenia, delusional disorder, and autism spectrum disorder in lone actors than the general population (Corner et al., 2016). The same authors suggested that a higher incidence of mental disorders among lone actors involved with terrorism in comparison with group actors (Corner et al., 2016).

In a short correspondence, Khoshnood (2017) concludes that the correlation between terrorism and mental illness is very weak. Based on his brief review of recent research, Khoshnood (2017) acknowledged the importance of studying radicalization's psychological factors. However, he concluded that mental illness does not play a major role in terrorism. His conclusion was based on a previous study conducted by terrorism experts (Alonso et al., 2008).

Another well-noted expert in the psychology of terrorism reported that only a minority of terrorists have a history of mental health issues (Horgan, 2005). However, Horgan's research, although

exclusive and insightful, is mostly limited to case studies. As he points out, an ongoing problem in terrorism research is the lack of access researchers have to the mental health information of terrorists. Most medical and psychiatric files on terrorists are likely to remain classified for security reasons, and mental health professionals who have access to such individuals are few. Horgan is one of the few premier researchers who has had the special privilege to interview terrorists and develop theories on the psychology of terrorism based on actual case studies.

In a theoretical article by Decety and colleagues (2017), the authors argued that radicalized individuals are mainly ordinary people, and that violent extremism does not appear to be caused by a brain disorder. The authors theorize that understanding terrorist psychology depends on a multilevel approach that integrates social, political, and economic perspectives with organizational and individual perspectives (Decety et al., 2017).

In support of the link between mental illness and terrorism, other researchers have found that terrorists are more likely to present with a history of psychosocial problems such as mental impairment, psychiatric examinations, post traumatic stress disorder, special education, violence, child abuse, criminality, anger, noncompliance with therapy, child behavioral issues, or any number of documented psychiatric illnesses such as borderline personality disorder, compulsive disorder, autism, and schizophrenia (Weenink, 2005; Merari et al., 2010a; Sahito et al., 2013; Meloy et al., 2017).

Weenink (2005) studied the police files of 140 subjects suspected of traveling or planning to travel from the Netherlands to Syria. He found that radical Islamists with a history of behavioral problems were overrepresented in these files, with 46% of the suspects exhibiting a "problem behavior." Additionally, the same study found that 6% of the sample presented with a personality disorder or mental illness. In these police files on terrorist suspects, there were indications of problem behaviors and mental illness, which included reports of mental impairment, institutionalization, child neglect, special education, persistent criminal offenses, child abuse, anger management, childhood trauma, tantrums, aggression, youth detention, and homelessness. Mental disorder diagnoses in the sample included psychosis, narcissistic personality disorder, ADHD, schizophrenia, autism spectrum disorder, and post traumatic stress disorder.

A subsequent review examined several personality disorders often suspected of terrorists, including narcissistic, paranoid, antisocial, and borderline personality disorders (Sahito et al., 2013). The study by Sahito and colleagues (2013) highlighted possible approaches to individual and group profiling of terrorists from a psychological trait perspective. These researchers proposed using psychological profiling and trait analysis as a way of guiding interrogations during counterterrorism operations.

Another study revealed that suicidal bombers were significantly more likely to present with avoidant-dependent personality disorder, depressive symptoms, and suicidal tendencies in comparison with non-suicidal terrorists and terrorist organizers (Merari et al., 2010a). Also, a forensic case study observed impulsive behavior in lone-actor terrorism (Meloy et al., 2017). Similar observations have been made of suicide bombers in comparison to non-suicide actors (Merari et al., 2010a).

Even if a purported link between mental illness and terrorism is found, there seems to be many limitations with applying psychiatric diagnoses and psychological profiling. Understanding terrorism is not just about psychopathology. Diagnosing a patient will help explain their constellation of symptoms, but it will not explain the motivation behind their behavior (Bhui et al., 2016). Understanding how individual and group processes converge offers a more comprehensive outlook on terrorist involvement. Terrorists come in a wide variety, which makes profiling impractical and even counterproductive. As one expert noted, "when we assume static qualities of the terrorist (a feature of profiles), we become blind to the quality of the dy-

namics that shape and support the development of the terrorist" (Horgan, 2008, p. 84).

We cannot fully understand terrorism in terms of any single fundamental cause or contributing factor, such as mental health. However, it is important to examine the commonality of psychological traits attributed to terrorism. They may reveal the neurological underpinnings of violent extremism. Ultimately, no definitive conclusion can be made on the role of mental illness in terrorism without evidence based on psychiatric interviews, neuropsychological testing, and neuroimaging reports. However, some useful interpretations of the available evidence can still be made. The current debate on the role of mental illness in terrorism will undoubtedly continue.

Violence, Aggression, and the Brain

The neural correlates of violence reside among various structures of the brain (Bogerts et al., 2018). Bogerts et al.'s (2018) review is truly the first of its kind and one of the only known articles to exclusively look at terrorist violence from a neuroscience perspective. One of the most intriguing observations regarding functional anatomy is that some of the same regions involved with violence and aggression are also involved with empathy (Bogerts et al., 2018), indicating that abnormal changes in these brain areas may have a dual impact on aggression and empathy alike. Empathy, or the ability to understand or share the feelings of others, is an essential trait of modern humans. Neuroscience literature has previously examined the relationship between impaired empathy and violence (Chialant, Edersheim, & Price, 2016). This study suggested that the prefrontal cortex and limbic system, under pathological conditions, are associated with violent behavior. In contrast, these same areas, under normal conditions, are associated with empathy.

Bogerts et al. (2018) reviewed various structural and functional imaging studies that found several cortical and subcortical limbic regions linked to aggression and violence. For example, violence and aggression may result from abnormalities in the cortical region, including lesions caused by trauma or tumors, decreased cortical volumes due to developmental problems, and reduced processing efficiency (Siever, 2008). Violence and aggression may also result from abnormalities in the limbic regions, including hyperactivity of the amygdala and related structures, reduced subcortical volumes, and emotional hypersensitivity (Siever, 2008).

Functional Neuroanatomy of Prefrontal Regions

The following sections will focus on prefrontal regions of the brain, as these areas are commonly associated with violence and aggression (Bogerts et al., 2018). The prefrontal cortex (PFC) constitutes one-third of the neocortex and is divided into the lateral (including ventrolateral and dorsolateral), medial, and orbitofrontal cortices (Fuster, 2001; Siddiqui, Chatterjee, Kumar, Siddiqui, & Goyal, 2008). The same authors provide the following information on regional prefrontal function. First, the lateral region is associated with language, attention, memory, response conflict, positive/negative attitude mediation, spatial reasoning, planning, novelty processing, creativity, and new learning. Second, the medial region is associated with bimanual coordination, attention to complex cognitive tasks, modulating arousal states, spatial memory, self-initiated movement, conflict resolution, decision making, long-term memory retrieval, and metacognition. Third, and finally, the orbitofrontal region is associated with reward expectations, emotional processing, delayed response, and behavioral self-regulation. In summary, PFC function is strongly associated with executive function, memory, intelligence, language, visual search, and gaze (Siddiqui et al., 2008). Notably, the orbitofrontal cortex is strongly linked to the amygdala, a limbic structure, forming an important circuit involved in violence and aggression.

Unique and common clinical symptoms characterize damage to each of the PFC subregions

(lateral, medial, and orbitofrontal cortices). Fuster (2001) describes them as follows: lesions in the lateral PFC are associated with the inability to organize and execute behaviors, speech, reasoning, and attentional control. Second, lesions in the medial PFC are associated with the loss of initiation of movement and speech, akinetic mutism, apathy, and impaired concentration. Third, lesions in the orbital PFC are associated with personality changes, impulsivity, irritability, disinhibition, amorality, and attentional deficits.

While regional specificity of functional anatomy is important, understanding the neural function of the PFC cannot be understood in isolation, but in the context of neural circuitry or the connections that the PFC has with other areas of the brain, including the brainstem, thalamus, and limbic system (Fuster, 2001). In other words, brain functioning is not exclusively localized to discrete areas but subserved by a complex network (Fuster, 2001). The PFC has reciprocal connections with all of the aforementioned regions except the limbic system's basal ganglia (Siddiqui et al., 2008). The PFC also has interconnections between its lateral, medial, and orbitofrontal subregions.

The following sections consider the segmental PFC areas that have been implicated in violence and aggression. A recent neuroimaging study found that violent offenders presented with reduced gray matter volume in the PFC and increased gray matter volume in the cerebellum and basal ganglia in comparison with non-violent controls (Leutgeb et al., 2015). Reduced gray matter volume in the PFC was also associated with psychopathy in the same subjects. Another study found reduced gray matter volume in the PFC in violent offenders and reduced functional connectivity of prefrontal areas with limbic areas (Contreras-Rodriguez et al., 2015).

Orbitofrontal Cortex (OFC). One review found that lesions in the orbitofrontal cortex were associated with increased aggression and impulsivity (Bogerts et al., 2018). In addition, reduced volume of the OFC was also observed in males with violent inclinations. This same review found that past studies have observed patterns of reduced gray matter volumes in the OFC, cingulate cortex, hippocampus, and insula in forensic and psychiatric populations. In particular, these structural abnormalities have been observed in criminals with psychopathy, in some psychiatric patients with schizophrenia or antisocial personality disorder, and in male prisoners with a history of violent offenses, including, but not limited to, homicide (Bogerts et al., 2018). Individuals with orbitofrontal lesions are more likely to have neuropsychiatric disorders, impaired social judgment, reduced empathy, and reflexive aggression (Brower & Price, 2001). An earlier review also found that both human and animal studies have implicated the PFC in aggression in cases where ablative brain surgery was performed on animals, in cases where humans underwent surgical or accidental lesions, in psychiatric patients, or in human subjects in experimental settings (Giancola, 1995). This review also found that the orbital region was more likely to be associated with disinhibited but non-aggressive behavior. In contrast, it was the dorsolateral region that was more likely to be associated with physical aggression. While some studies have been inconsistent in terms of orbital contributions to aggression, many studies point to this region as being a neural correlate of impulsivity (Winstanley et al., 2004).

Lateral Prefrontal Cortex (LPFC). The lateral PFC (LPFC) can be divided into dorsolateral and ventrolateral cortices. One review found that lesions in the dorsolateral cortex were associated with increased aggressive behavior (Brower & Price, 2001). The ventrolateral PFC is heavily involved in the cognitive control of memory, including semantic retrieval, episodic retrieval, post-retrieval selection, and task switching (Badre & Wagner, 2007). However, there seem to be limited studies on how the ventrolateral PFC contributes to violence and aggression.

In one meta-analysis by Yang and colleagues (2009), researchers analyzed 43 functional and structural neuroimaging studies on clinical

subjects characterized as antisocial. These individuals presented with any one of various disorders, including antisocial personality disorder, antisocial behavior, conduct disorder, oppositional defiant disorder, psychopathy, and individual histories of criminal behavior, violence, or aggression (Yang & Raine, 2009). This study found that individuals with antisocial personality disorder showed reduced prefrontal volume and reduced prefrontal activity. Specifically, these researchers found these reductions in various regions, including the left dorsolateral PFC, right orbitofrontal cortex, and right anterior cingulate cortex in brain scans of clinical subjects as compared to controls.

Medial Prefrontal Cortex (MPFC). In a recent review, one researcher found that dysfunctions in both the ventromedial prefrontal cortex and amygdala are associated with psychopathy, as well as impairments in reversal learning and increased reactive aggression (Blair, 2010). Experimental research has shown that ventral and dorsal aspects of the mPFC are implicated in social reactive aggression in healthy male subjects (Lotze et al., 2007). This study found increased activity in the mPFC in these subjects during an interactive fMRI task. Subjects exhibited increased dorsal mPFC activity while administering a retaliatory stimulus to their opponent during an fMRI task but exhibited increased ventral PFC activity while observing their opponent suffering. The medial PFC (mPFC) is primarily involved in memory and decision-making (Euston et al., 2012).

Functional Neuroanatomy of the Limbic System

The limbic system includes the olfactory bulb, hippocampus, amygdala, hypothalamus, basal ganglia, and cingulate gyrus. Of primary importance to the study of violence and aggression in terrorism are the amygdala, hypothalamus, and cingulate gyrus. The amygdala is nuclei located in the medial temporal lobe; the hypothalamus is in the frontal lobe, directly below the thalamus; and the cingulate gyrus is in the medial cerebral cortex, immediately above the corpus callosum. The amygdala is divided into central, basolateral, and superficial complexes (Rosell & Siever, 2015). It receives multisensory input and delivers motor signals to various other brain regions (Sah, Faber, Lopez de Armentia, & Power, 2003). The central complex generally projects efferent (motor) nerve fibers to subcortical regions and the brainstem. The basolateral complex generally receives afferent (sensory) nerve fibers from various cortical regions and the thalamus. Less is known about the superficial complex, however. Functionally, the amygdala is associated with emotional processing (including fear conditioning, aggression, and recognizing facial expressions), the hypothalamus with homeostatic function, and the cingulate gyrus with regulation of autonomic functions (Siddiqui et al., 2008).

However, brain functioning is not best understood in terms of discrete parts but by their interconnections. This is a maxim of neurology that is crucial for understanding neuropathology in violent extremism. For instance, a systems approach to understanding prefrontal-amygdala circuitry reveals that aggression can be understood in the context of top-down and bottom-up processes, with the orbitofrontal cortex and cingulate gyrus regulating aggression (through a top-down process analogous to a braking system), and the amygdala and insular triggering aggression (through a bottom-up process analogous to an accelerating system; Siever, 2008). The nature of violence from a neurological perspective should reveal a loss of balance between these two systems, with a hypoactive top-down process and a hyperactive bottom-up process.

Amygdala. A functional imaging study by da Cunha-Bang and colleagues (2017) found reduced amygdala-prefrontal connectivity and reduced striatal-prefrontal connectivity in violent offenders. These same authors found increased amygdala reactivity in this group (da Cunha-Bang et al., 2017). These findings indicate increased neural sensitivity in response to provocative stimuli, a characteristic that is often associated with aggres-

sion.

A review article by Davidson and colleagues (2000) argued that emotional dysregulation is a prelude to violence and aggression. The authors reported that the orbital frontal cortex, amygdala, anterior cingulate, and other associated regions are involved in emotional regulation. The PFC, in particular, received projections from neurons secreting serotonin, a neurotransmitter associated with regulating mood, social behavior, appetite, digestion, sleep, memory, and sexual function. A dysfunctional circuity involving the aforementioned regions may explain why individuals are more prone to impulsive aggression and violence due to emotional regulation problems. A recent review also found that bilateral volume reductions of the amygdala were associated with childhood aggression, reduced volume of the left central amygdala was associated with a lifetime history of aggression, and reduced bilateral volume of the amygdala was associated with adult men who were classified as aggressive (Pardini et al., 2014). Amygdala volumes were inconsistent in clinical samples of patients with psychopathy, however.

Development, Terrorism, and Neuroscience

The brain undergoes extraordinary structural and functional changes over time. Some areas generally develop earlier than others, and it is not uncommon to observe a healthy range of variability between individuals. Age and development have direct implications for human cognition and behavior, including rational decision-making. An examination of criminals or terrorists might reveal subjects with brains that are unlikely to have reached full maturation. Indeed, a review of terrorism research has indicated that terrorists typically join terrorist groups between 17-26 years of age (Loza, 2007). The inclination for adolescent and young adult recruitment and radicalization may be understood in terms of neurodevelopment, including developmental trajectories of cortical and subcortical regions. For instance, there appears to be a differential pattern of brain maturation where subcortical regions develop earlier and cortical regions develop later. Subcortical regions are generally associated with impulsive behaviors and primitive functions, whereas cortical regions are associated with rationalization and higher-order functions. Generally, the earlier the stage in brain development, the more time and potential the brain may have to adapt in response to stress, although resilience to stress decreases with aging. Such resiliency is present in the prefrontal cortex (McEwen & Morrison, 2013). While some lesions leave a permanent mark on cognitive or behavioral function, other injuries may be compensated for with cerebral reorganization, depending on the site and extent of the injury and chronological age. However, it is the connection between cortico-subcortical regions that may allow for regulatory functions to emerge. As such, neurodevelopment should be examined in terms of regional growth and system growth. According to research, understanding brain development is not only a matter of observing developmental changes in individual brain regions, but also the connections between regions, which are largely bidirectional and possess a hierarchical organization (Logothetis, 2008).

Neurodevelopment is tied to functional development, and as a consequence of late PFC development, higher-order functions such as logical reasoning develop later in life (Fuster, 2001). The PFC, in comparison with other cortical regions, is one of the last areas of the brain to undergo myelination and synaptogenesis, which are long-term maturational processes that often do not culminate until adolescence (Siddiqui et al., 2008). Recent neuroimaging research suggests that the prefrontal cortex does not fully develop until the third decade of the human life cycle (Fuster, 2015). These patterns of late-PFC maturation may be important in explaining violent extremism in terrorism from a neurodevelopmental perspective. It is plausible that individuals are more likely to become radicalized in these periods of adolescence and young adulthood when regulatory mechanisms are underdeveloped. However, this is speculative. Empirical

research is necessary to prove this claim.

In contrast, the amygdala develops early in life, with high rates of development occurring within two weeks of the postnatal period (see Tottenham, 2013, for review). There appears to be a sensitive time period in brain development where different regions are more susceptible to environmental influence. This kind of susceptibility is greatest during "peak periods" of neurodevelopment where specific brain regions are rapidly developing (Tottenham, 2013; Lupin et al., 2009). One researcher notes, "for some regions, like the prefrontal cortex, this period will be quite late and extended; for the amygdala, it will be early and rapid" (Tottenham, 2013, p. 4). Tottenham notes that the amygdala is particularly sensitive to environmental changes during early life.

Neurodevelopmental changes are non-linear (Gogtay & Thompson, 2010). In terms of brain volume, there is a pre-puberty increase in gray matter volume followed by a post-puberty decrease, which is explained by neurological processes of maturation, such as synaptic pruning and cortical myelination. In contrast, white matter volumes increase throughout the lifespan for several decades (Gogtay & Thompson, 2010). These changes in volumes are heterogeneous across lobes. Development is often prolonged, especially in the prefrontal region. The previously described changes in gray and white matter volume are best explained as a mechanism of improved efficiency of neural function during growth. Adult cognitive function is not so much dependent upon the number of brain cells in a given region as it is by the fine-tuned connections between cells and regions overall. Development of the PFC from 7 years to early adulthood is correlated with improvements in cognitive function, specifically with regard to processing speech, strategic thinking, working memory, and inhibition. These four abilities are linked to the dorsolateral prefrontal cortex in particular (Diamond, 2002).

There are unique behaviors associated with individuals in the adolescent-young adult age range, including increases in novelty-seeking and risk-taking (Spear, 2000). Young adults are considered to be between the ages of 20-35. The average age of the 9/11 hijackers was 24 (Central Intelligence Agency, 2008). Some suspected terrorists from other organizations also appear to fit within the young adult age range (Loza, 2007). For instance, according to a report by journalists from The Washington Post, a total of 125 individuals in the U.S. were charged by Federal prosecutors for activities in connection with the Islamic State, a jihadist militant group. This information was based on files from the U.S. Department of Justice. The average age of these individuals was 27 at the time that they were charged (Goldman et al., 2015). The age range for these individuals was 17-52.

Loza (2007) argued that some of the older terrorist leaders tend to promote martyrdom in recruits while being less likely to follow that pathway themselves. Similarly, another study conducted on the personality characteristics of suicidal terrorists, non-suicidal terrorists, or violent offenders and terrorist organizers found that both suicidal and non-suicidal terrorists had an average age of 19. In contrast, terrorist organizers had an average age of 27 (Merari et al., 2010b). This data is not surprising given the longstanding research on the age-crime curve, which shows that criminal behavior, including aggression, is correlated with males from adolescent or young adult age groups. Maturation of the brain occurs in adolescence and early adulthood, and this period is associated with a decrease in risk-taking behaviors, including criminal behavior, as the central nervous system fully develops (Blonigen, 2010).

Social Cognition, Terrorism, and Neuroscience

Social cognition encompasses several related constructs, including empathy, prosocial behavior, morality, and the regulation of violence and aggression (Decety et al., 2010). The aforementioned constructs are very important in mediating our social interaction with others. Dysfunctional social cognitive processes are often manifested as

problematic social behaviors, including violence and aggression, and may, perhaps, contribute to radicalization and associated terrorist activity. Investigating the neural mechanisms of social cognition is essential to understanding how terrorists become radicalized. Decety and colleagues (2010) argue that we can understand the neural correlates of radicalization by studying the psychological and demographic characteristics associated with extremism and analyzing patterns of brain activity in individuals with such characteristics in experiments designed to probe moral decision-making.

With the support of a social psychological model, Smith et al. (2020) proposed that radicalization is basically a group socialization process that unfolds during "situated social interactions" that optimize the influence of shared understanding and experiences. They claim, "people's radicalization to violence is inseparable from the social context in which their social interactions take place" (Smith et al., 2020, p. 327). In other words, terrorism is an evolving psychosocial process that develops within a group context and does not simply manifest itself from individual tendencies but from the influence of outside forces.

Results: Research Questions

Multiple perspectives are needed in terrorism studies given the complex interplay of genetic predispositions, individual psychopathology, socio-cultural determinants, and environmental conditions in shaping human behavior. Taken together, our exploratory case study and literature review generated research questions to be addressed through a hypothetical neuroscientific lens. Suggested research questions include:

- **Genetics**: Can our study of genes and neurodevelopment help us to predict violence and aggression in later adulthood?
- **Psychopathology**: Can neuroscientific research methods elucidate a causal or explanatory role for mental illness in the study of terrorism?
- **Psychopathology**: Is the potential for radicalization based on individual differences, i.e., age, socialization, personality, neurocognitive development, identified by neuroscientific measures?
- **Social-cultural**: Is empathy a mediator of aggression?
- **Social-cultural**: Can shared perspective-taking in groups and between siblings be explained by neuroimaging?
- **Social-cultural**: What are the neural correlates of religious fundamentalism?
- **Environmental**: Do environmental conditions impact neurodevelopment in such a way as to increase the probability of violent extremism?

Discussion: A Neuroscientific Conversation

Some researchers in terrorism studies often use inductive reasoning to infer potential brain abnormalities in terrorists based on clinical and forensic studies (Bogerts et al., 2018). That is, general principles regarding the neural correlates of violence in forensic and clinical populations are used to make probable but uncertain conclusions about terrorist suspects. Stronger evidence on the neuroscience of terrorism would certainly emerge if neuroimaging studies were to be conducted on these persons of interest. As researchers, we should readily acknowledge that there are problems with the external validity of whatever assumptions we make about the terrorist mindset, given the utter lack of informative case studies. However, we are responsible for attempting to fill the gaps in our information, although our degree of confidence will again, depend on the level of evidence on which we base our conclusions. In our case, using information from psychiatric and forensic research to apply toward terrorism research is, indeed, speculative, although it raises important questions for future research, such as the potential neural basis of violence, which appears to manifest itself in many different contexts. Neuroscience information on the terrorist population is limited because the number of available human subjects is limited, as terrorism is a rare phenomenon, and secondly because infor-

mation on these subjects is often classified due to national security reasons - and rightfully so.

I acknowledge the practical limitations that neuroscience would have within counterterrorism. Neuroimaging could only be used as a supportive analytical tool. In addition, while new evidence on the brain-behavior relationship is constantly emerging, there are still many unknowns in neuroscience.

Conclusion: The Role of Neuroscience in Understanding Terrorism

Some of the available sources that may shed light on the inner workings of the terrorist mind may include information obtained from psychiatric interviews, family narratives, military intelligence, legal proceedings, news reports, official media from terrorist organizations, and autobiographies by members or ex-members of terrorist groups. However, whatever inferences one makes should always be interpreted with caution. One should always remember the heterogeneous nature of the terrorist profile (Horgan, 2005). Generalizations should not be made as to the "neurological" characteristics of terrorists with a history of violent extremism, although some speculation is important for advancing our discussion of possible neural correlates of cognitive-behavioral traits commonly associated with this population. The role of neuroscience in understanding extremist violence may also contribute to policymaking in the legal system.

From a counterterrorism perspective, neuroscience is not a preventative tool but a supportive, analytical tool. The current psychiatric and forensic literature can help inform contemporary terrorism researchers in understanding brain-behavior relationships within the context of violent extremism. Future research should continue to investigate the functional anatomy of cognitive-behavioral traits associated with violent extremists, including violence and aggression, age-related patterns of radicalization, social cognitive processes such as empathy, and religious fundamentalism. In addition, researchers should reexamine potential links between terrorism and mental illness.

I strongly recommend that law enforcement and the intelligence community collaborate with professional neuroscientists within a legal framework in order to further investigate the neural correlates of violent extremism in terrorism. One cannot have a "multidisciplinary dialogue" about counterterrorism without neuroscience being part of the conversation.

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Cognitive Effects of Sleep Deficiency on Students' Mathematical Proficiency: A Review of the Literature

Guillermo Farfan
Florida State University

Mathematical proficiency relies on a host of cognitive processes that are shared with other mental functions, but three, in particular, are thought to play a central role: memory, attention, and executive functioning. This paper reviews some of the medical, psychological, and educational research literature on sleep deficiency and how it may affect one or more of these cognitive processes. It aims to provide a framework for future investigations into the mental processes of school-aged (K-12) and college-aged students that may be at risk from inadequate or insufficient sleep. Implications for mathematics teaching and learning are also briefly discussed.

Keywords: Sleep, memory, attention, executive function, mathematics achievement

Despite the essential role of sleep in the lifespan development of human beings, several studies have shown that children in the U.S. are not getting enough sleep, which has been associated with increases in stress levels, negative moods, and obesity (Millman, 2005; Short & Louca, 2015). It is estimated that sleep-related problems affect between 25% and 40% of U.S. youth (Meltzer & Mindell, 2006). These problems are not limited to the U.S., as similar patterns of inadequate sleep have been found in European and Asian countries (Gradisar et al., 2011). Although an increase in the use of electronic media and caffeine consumption has been cited as possible culprits in keeping some school-aged children awake longer (Calamaro et al., 2009), biological factors—such as changes associated with delayed evening onset of melatonin secretion—may be playing a role too (Owens, 2014; Owens et al., 2010).

In the sleep research literature, sleep deficiency is an umbrella term covering all phenomena related to inadequate or insufficient sleep. This includes sleep deprivation, sleep loss, sleeping at the wrong time of day, and sleep disorders that cause poor quality of sleep or disturbances in the sleep cycle (National Institutes of Health, 2011). Although less common, studies on the effects of sleep deficiency on academic performance are also found in the literature, primarily in adolescents and college students (Dewald et al., 2014; Kopasz et al., 2010; Meijer, 2008; Ming et al., 2011; Owens, 2014).

However, in these studies, the relationship between sleep and academic performance is often measured in broad terms, not independently of other measures. There is scant work on how poor or insufficient sleep may be affecting children's proficiency in specific subject areas, such as in mathematics. As an illustration, a quick search in one of the top journals in the field, Behavioral Sleep Medicine, returned only nine articles listed with the words "sleep," "school," and "mathematics," from 2007 to 2020. Of those, only two articles included measures to examine the relationship between sleep loss and primary students' academic performance in mathematics (Hiscock et al., 2018; Wolfson et al., 2007). A similar search for articles in another top journal, Journal of Sleep Research, returned five results of which only one publication involved using standardized measures of mathe-

matics achievement to check for correlations with sleep deficiency (Erath et al., 2015).

One reason for the shortage of sleep articles focusing on mathematics education is that accurately measuring sleep deficiency and its effects on academic performance is challenging (Meijer, 2008; Keller et al., 2008). Simultaneously, understanding the impact of sleep deficiency on academic subject areas has taken on a new salience as schools across the country are starting the school day earlier to meet curricular demands, cutting significantly into the sleep cycle of children (Owens et al., 2010). The school day is generally structured by grade level to cover varying subject areas at separate times of the day, and each subject area often uses different cognitive resources in distinctive ways (Klein, 2003; Meltzer et al., 2018). Thus, it should be expected that whatever adverse impact sleep deficiency has on children's academic performance, it would not affect all subject areas equally.

This paper reviews some of the medical, psychological, and educational research literature on sleep deficiency in school-aged (K-12) and college-aged students. The review focuses on a selective number of articles whose results have a bearing on the question: what cognitive effects of sleep deficiency may affect students' proficiency and academic achievement in mathematics the most? Articles consulted for this review ($N = 58$) were retrieved from the following databases: Educational Resources Information Center (ERIC), Google Scholar, the Medical Literature Analysis and Retrieval System Online (MEDLINE), and PsycINFO. The original search was limited to the years 2007 to 2017, though an effort has been made to include more recent work. Keywords used to search and identify relevant literature were "sleep deficiency," "sleep loss," "sleep deprivation," AND "children," OR "adolescence," OR "young adults." Also, the following keywords were added for K-12 mathematics: "elementary school," "middle school," "high school," AND "mathematics."

The structure of the paper is the following: the first section briefly summarizes the importance of sleep for human welfare. The second section overviews relevant literature examining the relationship between sleep deficiency and three cognitive processes that play significant roles in mathematical proficiency: memory, attention, and executive functioning. Finally, the last section discusses some of the implications of this literature to the teaching and learning of mathematics, including suggestions on how to mitigate these effects.

The Importance of Sleep

Adequate sleep is vital to the physiological welfare of animals, including all vertebrates and even some invertebrates (Raizen, 2012). At least four stages of sleep have been identified in nature, according to the most recent classification (Schulz, 2008): three stages of non-rapid eye movement (NREM) and one stage of rapid eye movement (REM). Only humans and some mammals manifest all four stages and physiological sub-states of sleep, including those associated with slow-wave sleep (SWS), which is the last stage of NREM and most predominant in the early hours of sleep (Backhaus et al., 2007; Mader & Mader, 2016).

Sleep appears to have played many roles in the evolution of animals, such as metabolic homeostasis, defense and response to injury, and timed biological growth (Mader & Mader, 2016). Sleep also seems to have played an evolutionary role in both learning and memory consolidation, which is the stabilization of previously encoded information. Without consolidation, any positive or negative experience that an animal could learn from would be rapidly forgotten (Vorster & Born, 2015), which in turn lessens its chances for survival (Raizen, 2012).

In humans, consolidation of memories during sleep is dependent on the hippocampus (e.g., declarative memory) rather than memories that are independent of it (e.g., non-declarative memory; Carlson, 2013). Nonetheless, many studies have shown that both types of memories are boosted during sleep and that the prefrontal–hippocampal system is involved in both (Dotto, 1996;

Vorster & Born, 2015). At the same time, memory consolidation during sleep is not the same across the board but depends on several different factors, such as the kind of material or content to be learned and a person's age (Diekelmann et al., 2009).

Experts believe that children aged 5 to 10 years old should get between 9 to 10 hr sleep, while older children should get at least 8 hr (Biggs et al., 2011). It must be noted, however, that the recommended number of sleeping hours has trended downwards historically with little supporting evidence (Matricciani et al., 2012). Nonetheless, as will be discussed below, many adverse effects of poor or insufficient sleep are well documented (Astill et al., 2012; Gohar et al., 2009), including some of the neuro-mechanisms behind cognitive impairment after sleep loss (Halassa et al., 2009). Sleep deprivation, for instance, has been found to increase reaction times when accessing working memory for simple verbal and arithmetic tasks (Jiang et al., 2011), as well as altering one's mood and stress levels (Owens, 2014).

To study sleep, scientists rely heavily on electrophysiological instruments, such as electroencephalographic (EEG) and electrooculographic (EOG) recordings, as well as behavioral tasks and self-reported measures (Bryant & Gomez, 2015; Mader & Mader, 2016). Despite the number of tools at researchers' disposal, however, there are many unresolved questions regarding the effects of sleep deficiency on the academic performance of children, including in the subject area of mathematics, to which I now turn.

Cognitive Aspects of Sleep and Mathematical Proficiency

At its most basic level, mathematical thinking draws from many of the same cognitive resources that are available for thought processes in general (Phillips, 2014; Tall, 2013), such as symbolic and non-symbolic reasoning (Matejko & Ansari, 2017), visuospatial memory (Verdine et al., 2017), and language (Dehaene et al., 1999). Consequently, long-term development of mathematical proficiency is likely dependent on a subtle interplay of many cognitive and non-cognitive factors without relying on a fixed knowledge structure (Howes et al., 2019; Kilpatrick et al., 2001; Tall, 2013; cf. Schneider & McGrew, 2012).

Among the various cognitive processes underlying proficiency in mathematics (Schoenfeld, 1985), three, in particular, are thought to be closely associated with sleep: memory, attention, and executive functioning (Raghubar et al., 2010; Schmitt et al., 2017). The next section provides an overview of the literature on poor or insufficient sleep and how it may disrupt one or more of these three processes.

Memory

Memory, or the ability to encode, store, and retrieve information, is one area where substantial evidence on the effects of sleep deficiency has been collected (Rasch & Born, 2013; Swanson & Beebe-Frankenberger, 2004). It is known, for instance, that both SWS and REM sleep are involved in long-term memory consolidation, specifically declarative and non-declarative memories (Dotto, 1996; Maquet, 2001). For example, in mathematics, the memorization of number facts, terms, and formulas is a function of declarative memory (Andersson, 2010; Bayram, 2004). On the other hand, the computational aspects of an algorithm (e.g., long division) involve several mechanical steps that rely in part on non-declarative or procedural memory (Evans & Ullman, 2016; Van Putten et al., 2005). Since both types of memory seem susceptible to loss of SWS and REM sleep (Kopasz et al., 2010), it could be expected that reducing sleep hours will have some effect on children's memory consolidation and thus on their mathematical proficiency.

Studies combining electrophysiological and behavioral measures have shown that SWS particularly enhances declarative memories, such as cued recall, whereas REM sleep preferentially supports non-declarative memories, such as procedural and emotional aspects of memory (Maquet,

2001; Deak & Stickgold, 2010). Significantly, the strength of these associations appears to vary with age. For instance, an experimental study investigated the effects of SWS on declarative memories among 16 middle-aged (ages 48 to 55) and 14 young adults (ages 18 to 25) by observing participants' recall ability after two nights of sleep under laboratory conditions (Backhaus et al., 2007). Each subject in the study spent one night of short sleep (3.5 hr) and another night of late sleep (two sessions of 3.5 hr each) in counterbalanced order, with a cool-off period of one week between sessions. Using a word-pair cued recall task to test for declarative memory, the authors reported that memory retrieval in the early sleep condition among middle-aged adults was significantly worse than in young adults after controlling for other factors, suggesting that the former's declarative memories benefitted less from SWS overall (Backhaus et al., 2007). These results, which have been corroborated elsewhere (Mander et al., 2017; Rasch & Born, 2013; Spencer et al., 2007), indicate a likely change in the functional link between SWS and declarative memory over time. Presumably, as people age, there is less benefit from SWS because they encode less information ("synaptic downscaling;" Backhaus et al., 2007; Scullin, 2013), particularly if the information to be encoded is non-episodic in nature (Aly & Moscovitch, 2010; Diekelmann et al., 2009).

There is also evidence that younger children benefit from sleep differently than do older children and adults. In another study (Wilhelm et al., 2008), 15 children (ages 6 to 8, 9 females) and 15 young adults (ages 25 to 28, 13 females) were recruited to examine the dissociated effects of sleep on procedural and declarative memories after learning. The authors used a word-pair associate learning task and a 2D object location task to assess participants' declarative memories and a finger sequence tapping task to assess their procedural memories. For each participant, learning of tasks took place either right before sleep ("sleep" condition) or after awakening in the morning ("wake" condition), alternating the order in which participants experienced these conditions (Wilhelm et al., 2008). As expected, recall in the word-pair and 2D object tasks were better for both age groups in the sleep condition, but the same was not true on the procedural task: despite spending more time in both SWS and REM sleep, young children performed worse overall in finger tapping in the sleep condition than in the wake condition, which is the opposite to young adults (Wilhelm et al., 2008). The authors suggested that procedural encoding in young children may take place during waking hours rather than during REM sleep. These differential effects have been observed in other studies with young children (Astill et al., 2012; Fischer et al., 2007; Rasch & Born, 2013).

Together, these reports suggest that the relationship between long-term memory consolidation and SWS and REM sleep varies with age. Indeed, there is considerable evidence that such a relationship is at its strongest during adolescence and that adolescents are highly capable of compensating for short periods of severe sleep loss or deprivation (Astill et al., 2012; Gradisar et al., 2008; Wilhelm et al., 2012). Importantly, adolescence is also a critical period in children's mathematics education as many of the subjects taught during these years (e.g., algebra, geometry) serve as a foundation for future studies in college and beyond (Bayram, 2004; Bush & Karp, 2013; Welder, 2012). Moreover, as mentioned earlier, students make use of both declarative and non-declarative memories to master these subjects (Andersson, 2010; Evans & Ullman, 2016). Given that sleep deficiency curtails both SWS and REM sleep, it may have negative consequences on children's consolidation of these memories and indirectly interfere with their learning of mathematics.

Not only is sleep deficiency potentially damaging to long-term memory consolidation, but it may also have negative effects on working memory (W.M.), which is the ability to temporarily maintain and manipulate pertinent information (De Smedt et al., 2009; Unsworth & Redick, 2017). The importance of W.M. for mathematics proficiency

is well documented. It is known, for instance, that W.M. plays an important role in computation and problem-solving skills (Rassmussen & Bisanz, 2005; Spybrook, 2008), and children with mathematics learning disabilities often display difficulties in their W.M. (De Smedt et al., 2009; Swanson & Beebe-Frankenberger, 2004); additionally, W.M. capacity is a strong predictor of later mathematics achievement (Friso-van den Bos et al., 2013; Passolunghi et al., 2007).

Evidence suggests that poor or insufficient sleep negatively affects W.M. (De Bruin et al., 2017; Kopasz et al., 2010), but it remains unclear what amount of sleep loss is detrimental. For example, there is evidence that adolescents tend to do worse in W.M. tasks when they report being repeatedly sleep-deprived. In a study by Gradisar et al. (2008), 143 adolescents, ages 13 to 18 (M = 14.9 years old, 81 females), were classified as sufficient sleepers (> 9 hr), borderline sleepers (8 to 9 hr), or insufficient sleepers (< 8 hr) based on their responses to a sleep survey. Using both a letter-number sequence and an operation span task to assess W.M., the authors found that adolescents in the insufficient sleep category performed worse, on average, on both W.M. tasks compared to borderline sleepers (Gradisar et al., 2008). This was most evident in the operation span task, which required participants to shift their attention from word list items to mathematical equations. The authors reported insufficient sleepers scored worse overall on this task than borderline sleepers and that the effect size was large (d = 0.92) even after controlling for general intelligence. However, there was no significant difference in performance between insufficient and sufficient sleepers in the operation span task, suggesting that frequently sleeping more than 8 or 9 hours may in some cases be as damaging to W.M. as sleeping less (Gradisar et al., 2008; see also Dewald-Kaufmann et al., 2013; Van Oostrom et al., 2018).

Conversely, there are instances where children can compensate for short periods of sleep loss while engaging their W.M. (Astill et al., 2012; Kopasz et al., 2010). A paper by Steenari et al. (2003) examined the relationships between quality and quantity of sleep and performance in auditory and visual W.M. tasks among 60 children, ages 6 to 13 (M = 9.9 years old, 31 females). To measure their sleep, children wore wrist-sized actigraphy devices for 72 consecutive hours. The W.M. tasks consisted of either auditory or visual items with three different cognitive load levels, with the number of items increasing or decreasing while keeping the other features constant (n-back task paradigm). Children performed these tasks on a computer on separate days under controlled conditions (Steenari et al., 2003). The authors found that impairment of W.M. was only noticeable in those with acute sleep loss during the highest cognitive load tasks, and that time spent asleep (i.e., all NREM and REM stages) was a better predictor of W.M. performance than total sleep duration (which includes time before falling asleep and shortly after waking up; Steenari et al., 2003). This is consistent with other studies that observed compensatory mechanisms among adolescents with chronic sleep loss during W.M. tasks, similar to those found in adults (Beebe et al., 2009; De Bruin et al., 2017; Kopasz et al., 2010).

In sum, poor or insufficient sleep often affects SWS and REM sleep, which in turn may interfere with the consolidation of declarative and non-declarative memories that are needed to learn mathematics. Moreover, while short-term compensation is possible, sustained sleep loss can also decrease W.M. performance, which could result in a failure to remember instructions, lack of coordination, and an inability to keep track of and complete mathematics learning activities (De Smedt et al., 2009; Swanson & Beebe-Frankenberger, 2004).

Attention

Another cognitive process that is important for mathematical proficiency is attention (Mason, 2003; Schoenfeld, 1985). Also known as vigilance, attention is the ability to select and retain relevant information for prolonged periods, and it can be further separated into three types: attention to rele-

vant stimuli only (selective attention), attention to two or more tasks simultaneously (divided attention), and attention to one specific task without distraction (sustained attention; Belísio et al., 2016; De Bruin et al., 2017). To measure the effects of poor or insufficient sleep on attention, researchers often make use of psychomotor tasks that require quick responses to stimuli without getting distracted, selection and discrimination tasks, and cognitive and neuropsychological models (Belísio et al., 2016; Peng & Miller, 2016). These measures are frequently combined with psychometric scales to yield more accurate results (Jugovac & Cavallero, 2012).

In mathematics, attention regularly plays a critical role as it helps students focus, for example, on certain features that may be mathematically relevant for a task (e.g., vertices on a polygon) while disregarding others that are less likely to be so (e.g., color of lines in a figure). Moreover, it has been shown that attention correlates with numerosity and number processing (Anobile et al., 2013), that attention training can, in some cases, increase student mathematical performance (Zilaey et al., 2017), and that attention deficits often predict students' difficulty with solving complex mathematical tasks (Geary et al., 2007).

Evidence does exist that poor or insufficient sleep can have detrimental effects on attention. For instance, Jugovac and Cavallero (2012) examined the impact of one night of sleep deprivation on young adults' ability to achieve an alert state (alerting), select relevant information (orienting), and resolve conflicting stimuli (executive control). Thirty college students (ages 20 to 29 years old, 24 female) were assigned to one night of regular sleep (at home) and one night without sleep (in the laboratory), in alternating order (Jugovac & Cavallero, 2012). In addition to sleepiness and mood scales, participants completed a battery of attention psychomotor tasks, which involved identifying the left/right direction of arrows on a screen preceded by a cue (how these cues were presented to participants prompted their alerting, orienting, or executive control mentioned earlier; Jugovac & Cavallero, 2012).

Results showed average reaction times and accuracy among young adults were lower after one night of sleep deprivation than under normal sleep conditions (Jugovac & Cavallero, 2012). However, a closer look revealed participants' attention being affected selectively: the authors found no significant differences in alerting or orienting performance under either sleep condition, whereas executive control significantly decreased after one night without sleep (Jugovac & Cavallero, 2012). This suggests that, rather than causing a general drop in attention, losing sleep led to a selective impairment in participants' executive control only. Although other studies have shown comparable results (Choudhary et al., 2016; Short & Banks, 2014), considerable variation in the ability to attend to and resolve conflicting stimuli has also been reported, often attributed to individual differences or task-specific features (Eaves et al., 2020; Whitney et al., 2017).

Similar adverse effects on attention have been observed in adolescents while emulating more realistic conditions. In a study by Agostini et al. (2017), the effects of insufficient sleep on adolescents' sustained attention were examined using a combination of polysomnography, psychomotor tasks, and a sleepiness scale. Twelve high-school students, ages 15 to 17 (M = 16.1 years old, six female), were recruited for a simulated school week under laboratory conditions comprising of two nights with 10 hr of sleep, followed by five nights with 5 hr of sleep, and another two nights with 10 hr of sleep. To measure attentional deficits, the authors used the Psychomotor Vigilance Task (PVT), which consisted of pressing a button as soon as a red counter appeared on the screen at random intervals of 1 to 10 s. The authors found that attentional lapses increased immediately after sleepless nights, with the worst PVT performance happening during the morning hours (Agostini et al., 2017).

Interestingly, the last two nights with 10 hr of sleep—which were meant to resemble a "week-

end" of sleep recovery—were insufficient to restore baseline performance, even though participants subjectively thought it did (Agostini et al., 2017; see also Lo et al., 2016). This could have important implications for those students whose mathematics classes start early in the day, as they may find performing mathematical tasks that require sustained attention more difficult depending on the time of day, although the evidence for it remains inconclusive (Sjosten-Bell, 2005; Wile & Shouppe, 2011).

Aside from these findings, however, a few systematic and meta-analytical reviews have found mixed results with regards to the effects of sleep deficiency on attention in children and young adults. For instance, Astill et al. (2012) evaluated 86 studies with a total of 35,936 children (ages 5 to 12) to identify associations between sleep and measures of cognitive performance. Contrary to what is usually reported in adults, they found no significant relationship between sleep duration and sustained attention as measured by psychomotor tasks (Astill et al., 2012). De Bruin et al. (2017) examined similar associations across 16 studies involving adolescents (ages 10 to 19) and found that complete lack of sleep (deprivation) does affect attention in general, but a shorter sleep schedule did not. Finally, Lowe et al. (2017) reviewed 61 studies that include 1,688 participants of various ages (M = 28.74 years old) and found a significant negative effect of shorter sleep on sustained attention but no significant effects on selective or divided attention.

Accordingly, it appears that poor or insufficient sleep could have negative effects on some forms of attention (e.g., sustained), but it is unclear how severe or to what extent outside laboratory conditions (Belísio et al., 2016; Jugovac & Cavallero, 2012). Nonetheless, if attentional deficits do occur, they may persist and not be easily recuperated (Agostini et al., 2017; Lo et al., 2016). Because proficiency in mathematics often requires being able to attend to mathematically relevant details (Booth et al., 2017; Kaminski & Sloutsky, 2013), attentional deficits caused by poor or insufficient sleep could result in lower mathematics achievement over the long run.

Executive Functioning

Executive functioning (E.F.) is often described as an amalgamation of cognitive resources that are involved in goal-directed behavior, inhibitory control, and cognitive flexibility (Schmitt et al., 2017; De Bruin et al., 2017). As such, E.F. builds on the mechanisms of both memory and attention, such as retrieving relevant information during a task or suppressing likely distractors (Cragg et al., 2017). More importantly, mathematical proficiency often depends on an interplay between domain-general skills that E.F. presumably supports and domain-specific knowledge or skills particular to mathematics. For instance, solving a complex arithmetic problem may require selecting an appropriate strategy, holding interim solutions in mind during computation, ignoring unwanted number facts during retrieval, and switching between different number representations (Gilmore & Cragg, 2018). Because mathematics draws on such a wide array of underlying skills, many experts think children and young adults must rely on E.F. to become proficient in mathematics (Best et al., 2011; Schmitt et al., 2017).

Yet, given E.F.'s dependence on lower-level mechanisms, it is considerably more difficult to disentangle and assess the effects of sleep deficiency on E.F. than is the case with either attention or memory (De Bruin et al., 2017; Nguyen et al., 2019). Nonetheless, a handful of studies have attempted to examine whether poor or insufficient sleep negatively impacts E.F. A study by Tucker et al. (2010), for example, investigated the effects of sleep deprivation on E.F. in 23 young adults (ages 22 to 38, 11 female). Participants were randomly assigned to either two nights of total sleep deprivation or a sleep-as-usual (control) condition and spent six days in the laboratory completing a battery of tasks, some of which were designed to disassociate elements of their E.F. (Tucker et al., 2010). Results showed that overall performance on tasks declined during total sleep deprivation, but

the effects of sleep deficiency on E.F. were not uniform across the board: impairment was observed in a psychomotor and a W.M. (Sternberg) task, but neither the time taken to retrieve an item from W.M. nor the ability to suppress likely distractors—core elements of E.F.—appeared significantly damaged despite total sleep deprivation (Tucker et al., 2010). Likewise, Skurvydas et al. (2020) randomly assigned 30 young adult males (M = 20.2 years old) to either one night of complete sleep deprivation or a control group to assess cognitive and psychomotor effects of sleep loss. The authors reported that young adults in the sleep deprivation condition significantly underperformed on E.F. tasks compared to control, but there were no significant differences in motor skill or attention tasks (Skurvydas et al., 2020).

Impairment of E.F. due to sleep loss has also been observed among adolescents. Cohen-Zion et al. (2016), for instance, examined the effects of insufficient sleep on the cognitive performance of 45 adolescents (M = 16.9 years old, 18 female) after four nights of restricted sleep (6 to 6.5 hr) and four nights of extended sleep (10 to 10.5 hr) in counterbalanced order. Using a battery of tests that included a Go-No Go task, a Stroop test, and a psychomotor task (Catch game) to assess E.F., the authors found that adolescents' ability to process information was significantly lower under the restricted sleep condition than the extended sleep condition and that these changes in information processing were positively correlated with their performance in E.F., motor skill, and attention tasks (Cohen-Zion et al., 2016). These results suggest that adolescents suffering from chronic sleep loss may have fewer available cognitive resources for E.F., presumably due to deficits in the prefrontal cortex (Satterfield & Killgore, 2019). This may cause them to reduce the amount of effort they put in processing and solving tasks that require E.F. (Cohen-Zion et al., 2016; Engle-Friedman et al., 2003).

There is also interest in how sleep helps or hinders the E.F. of young children, particularly because E.F. deficits are often associated with developmental disorders such as attention deficit hyperactivity disorder (ADHD), disruptive behavior disorder (DBD), and autism spectrum disorders (ASD; Kenworthy et al., 2014; Schoemaker et al., 2012). As is the case with adolescents and young adults, some evidence exists that poor or insufficient sleep negatively impacts children's E.F. For example, a five-day study by Sadeh et al. (2003) examined the effects of sleep restriction among 77 fourth- and sixth-grade children, ages 9 to 12 (M = 10.6 years old, 38 females). On the third night, participants were randomly assigned to either a sleep extension (1 hr more) or a sleep restriction (1 hr less) condition for the remaining of the study (Sadeh et al., 2003). Results showed that children in the sleep extension condition performed significantly better on a digit span E.F. task (measuring memory retrieval) and a continuous performance E.F. task (measuring sustained attention and inhibitory control) compared to children in the sleep restriction condition. The authors further noted that both E.F. tasks are highly correlated with reading and mathematics achievement (Sadeh et al., 2003).

Similarly, Molfese et al. (2013) examined the effects of a 1-hr sleep restriction on the brain activity of six young male children (ages 6 to 8) across three tasks measuring attention, speech perception, and E.F. (Directional Stroop test). Participants wore a geodesic sensor net and were assessed on these tasks after one week of an ideal 9:00 pm to 7:00 am sleep schedule and one week of a 1-hr delayed sleep schedule (tasks were presented in counterbalanced order). Results showed that children had less brain activity and performed worse in the Directional Stroop test following restricted sleep than after the ideal sleep schedule, suggesting that the attention and inhibitory control elements of their E.F. did not benefit from a shorter sleep period (Molfese et al., 2013).

On the whole, these results suggest that sleep deficiency may affect certain elements of E.F. in school-aged and college-aged students; however, it is important to note that research on sleep and

E.F. is not without controversy (Pace-Schott et al., 2009). Astill et al. (2012) noted in their meta-analysis that most studies report sleep duration but not time spent asleep, and for those who do report the latter, no significant correlations with E.F. were found. Another meta-analysis (Lowe et al., 2017) found sleep restriction had a small but significant negative effect on E.F.; however, this effect was inconsistent across studies. Finally, De Bruin et al.'s (2017) systematic review found some studies showing decrements in performance on E.F. tasks after poor or insufficient sleep, whereas in other similar studies using different E.F. tasks, there was no effect.

Some of these inconsistencies in results may be attributed to issues of measurement. As pointed out earlier, given that E.F. is thought to depend on other, lower-level cognitive mechanisms, disentangling what aspects of E.F. are directly affected by sleep deficiency would be difficult to do even in the event of reliable and valid measures (Nguyen et al., 2019). There is also the possibility that failure to observe effects on E.F. after little or no sleep might be attributed to individuals' use of coping strategies to help mitigate the negative effects (Pace-Schott et al., 2009). Nevertheless, empirical evidence supports the idea of a connection between poor or insufficient sleep and deficits in E.F. If so, this relationship can have important implications for mathematics achievement, as many of the skills needed for mathematical proficiency—from retrieving number facts to attending to structure—are connected in one way or another to students' E.F. (Cragg et al., 2017; Espy et al., 2004; Gilmore & Cragg, 2018).

Discussion

Mathematical thinking relies on a host of cognitive processes that are shared with other mental functions (Tall, 2013; Schoenfeld, 1985). Of those, three have been recognized in this paper as important for becoming proficient in mathematics: memory, attention, and executive functioning. The studies reviewed here investigated the effects of sleep deficiency on one or more of these cognitive processes and provided some important, albeit at times conflicting, results.

The effects of poor or insufficient sleep on memory, in particular, appear to have the most consistent results. There is strong evidence that SWS and REM sleep are essential for long-term memory consolidation and that restricted sleep can interfere with this process (Astill et al., 2012; Owens et al., 2010; Wilhelm et al., 2012). Additionally, the strength of the relationship between sleep and memory consolidation appears to vary with age, with adolescents benefiting the most from sleep (Gradisar et al., 2008; Wilhelm et al., 2012). Moreover, the timing and stages of sleep, rather than the gross amount of sleep hours, are more important for memory consolidation (Astill et al., 2012; Gruber et al., 2014). Working memory also seems affected by sleep deficiency, as a decrease in performance on W.M. tasks was observed after restricted or lack of sleep (Gradisar et al., 2008; Kopasz et al., 2010; Steenari et al., 2003). Although children and young adults are capable of compensating somewhat for these negative effects, sustained sleep loss could result in disruption of both declarative and non-declarative memories, as well as failure to recall or keep track of relevant information when completing mathematical tasks (De Smedt et al., 2009; Swanson & Beebe-Frankenberger, 2004).

The effects of sleep deficiency on attention and E.F. are less apparent but nonetheless seem to exist. For example, there is evidence that attentional deficits do occur after lack of sleep (Jugovac & Cavallero, 2012; Short & Banks, 2014), though these deficits may vary depending on the individual or task (Eaves et al., 2020; Whitney et al., 2017). Furthermore, a time for sleep recovery—such as a weekend—may be insufficient to recoup some of these deficits (Agostini et al., 2017; Lo et al., 2016). How much of this is long-lasting or translates into the classroom is difficult to ascertain, though given that mathematical tasks often require high levels of sustained attention, any deficits caused by poor or insufficient sleep could be detrimental (Belísio et

al., 2016; Booth et al., 2017; Geary et al., 2007).

Similarly, there is evidence that poor or insufficient sleep can affect E.F. and thus interfere with mathematical proficiency. Some studies with children and young adults have observed declines in psychomotor and W.M. skills (Tucker et al., 2010), processing speeds (Cohen-Zion et al., 2016), inhibitory control (Sadeh et al., 2003), and brain activity (Molfese et al., 2013) after restricted or lack of sleep that correlates with poorer performance in E.F. tasks (Skurvydas et al. (2020). However, open questions remain as to whether sleep deficiency affects executive functioning inconsistently (De Bruin et al., 2017; Lowe et al., 2017) or in some cases not at all (Pace-Schott et al., 2009) due to measurement issues, or if the associations between performance in E.F. tasks and mathematics achievement is due to individual components of E.F. or a single latent E.F. factor (Nguyen et al., 2019).

It must be noted that the negative implications of sleep deficiency in children and young adults are in no way limited to the three cognitive processes highlighted here. There is mounting evidence that students who do not receive adequate sleep have poor academic performance, not just in mathematics (Bryant & Gomez, 2015; Dewald et al., 2014; Keller et al., 2015; Ming et al., 2011). Additionally, sleep deficiency in school-aged children—particularly adolescents—is frequently associated with adverse behavioral and affective well-being effects, including fatigue, irritability, depression, and anxiety (Gruber, 2013; Owens, 2014; Wrzus & Wagner, 2014). In turn, these effects may interfere with academic performance and success by, for instance, decreasing motivation and taking away the cognitive improvements brought by positive moods (Grootenboer & Hemmings, 2007; Pourtois et al., 2017; Singh et al., 2010). There is also evidence that sleep deficiency may affect male and female students differently (Bos et al., 2009; Meijer, 2008; Short & Louca, 2015).

In short, the findings reviewed here suggest that school-aged and college-aged mathematics students have much to lose (and nothing to gain) from poor or insufficient sleep. The cognitive effects of sleep deficiency can range from disruption of long-term memory consolidation to impairment of W.M. and E.F., and these effects may start showing in as little as having one hour less of sleep (Gradisar et al., 2008; Molfese et al., 2013; Sadeh et al., 2003).

Implications for Mathematics Teaching and Learning

Mathematics is one of the most cognitively demanding subjects in school (Andersson, 2010; Cragg et al., 2017; Gilmore & Cragg, 2018; Passolunghi et al., 2007), and students who suffer from poor or insufficient sleep may already be at a disadvantage cognitively compared to their peers (Erath et al., 2015; Lo et al., 2016; Maski & Kothare, 2013). This could manifest in several ways, such as difficulty accessing prior knowledge while problem-solving, frequent mistakes due to inattention, or slowness in completing routine mathematical tasks. Thankfully, the literature provides some direction as to what can be done to ameliorate the effects of sleep deficiency on students' proficiency and achievement in mathematics.

The most obvious recommendation is to allow children and young adults the opportunity to sleep adequately at night (Biggs et al., 2011; Matricciani et al., 2012). This may be easier said than done, as there might be a mismatch between the onset of biological changes and fixed school demands—for example, adolescents' willingness to stay up late but having to wake up at the same early time of the day (Borlase et al., 2013; Keller et al., 2015; Owens, 2014). Nonetheless, sleep hygiene such as not drinking caffeinated drinks or eating late in the evening, setting up a time for winding down, turning on blue light filters on display devices, or turning off devices are all recommended steps to ensure good quality of sleep (Bryant & Gomez, 2015; Owens, 2014; Suni, 2020).

Additionally, it is important to avoid oversleeping on non-school days, particularly for ad-

olescents and young adults. This may seem paradoxical, as it is commonly believed that sleeping for longer on weekends can compensate for sleep loss; however, evidence suggests that doing so may exacerbate problems with falling asleep on time (Bryant & Gomez, 2015; Taylor et al., 2008), and in any case, oversleeping for one or two days appears ineffective in compensating for deficits accumulated during the week (Agostini et al., 2017; Lo et al., 2016).

Mathematics teachers can also assist students with poor or insufficient sleep by delaying the introduction of cognitively demanding tasks at the beginning of a lesson or avoid putting students who are known to suffer from sleep deficiency in overly stressful situations (Dewald et al., 2014; Maasar et al., 2019). This will depend on reliably identifying such students early, and there is some evidence that preventive, school-based sleep interventions can work in that regard (Gruber et al., 2016). Finally, delaying school starting times may allow students to sleep longer (Borlase et al., 2013; Bryant & Gomez, 2015; Wolfson et al., 2007); however, some studies found no evidence that time-of-day has any effect on mathematics achievement (Davis, 1987; Sjosten-Bell, 2005). This may be because delaying school start on its own does not guarantee children are getting sufficient sleep, as much still depends on other medical and socio-economic factors (Keller et al., 2015). Conversely, individual differences in mathematical ability and coping mechanisms also play significant roles in mathematics achievement (Gilmore et al., 2017; Skaalvik, 2018). Thus, overcoming the negative effects of poor or insufficient sleep most likely depends on a collective effort rather than on a single solution (Borlase et al., 2013).

Conclusion

The time spent sleeping constitutes about one-third of one's life, and yet many children and young adults today are getting less sleep than before (Millman, 2005; Owens, 2014). Proficiency in mathematics relies on cognitive processes that are often susceptible to sleep loss, particularly memory, attention, and executive functioning. By highlighting how poor or insufficient sleep may interfere with these processes, the literature reviewed here should be useful not only to researchers but to parents, students, and other stakeholders who get to make important decisions regarding sleep and mathematics achievement.

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Is Ignorance Bliss: The Relationship Between News Exposure and Mental Health

Rebecca Reidy Bunn
The New School for Social Research

Antonina Farmer
Randolph-Macon College

News exposure has yet to be studied as a daily hassle contributing to anxiety. This study aimed to (1) establish if a relationship between news exposure and anxiety levels exists, (2) evaluate whether anxiety levels change over time in relation to news exposure, and (3) establish if emotion regulation moderates these relationships. Participants reported their news exposure, psychological symptoms, intolerance of uncertainty, psychological flexibility, and perseverative thinking. Five hundred and two participants were in the initial sample, followed by 304 in Wave 2 and 305 in Wave 3. About half of the participants were daily consumers of news. Controlling for age, there was no direct correlation between news exposure and anxiety levels concurrently or prospectively. Participants' access to news did not significantly differ between waves. Wave 1 news-related variables did not predict anxiety at Wave 1 or 2. Overall, participants who experienced greater enjoyment from the news were less stressed and had greater psychological flexibility. Prospectively, they were less likely to be depressed, controlling for initial levels. Greater exposure and less news enjoyment predicted more intolerance of uncertainty prospectively. Overall, those who reported high levels of depression reported lower levels of engagement and enjoyment from the news while having higher intolerance of uncertainty, perseverative thinking, and less psychological flexibility. Although our findings did not support our hypothesis about anxiety, news exposure and level of enjoyment from news predicted other areas of psychological distress. This indicates a need for more nuanced research on the relationship between news exposure and mental health outcomes.

Keywords: news, daily hassles, depression, anxiety, uncertainty

According to the Anxiety and Depression Association of America, anxiety disorders are the most common mental illness in the United States, affecting approximately 18% of the adult population yearly (2019). Kessler and colleagues (2012) found that in the United States, the lifetime prevalence of anxiety disorders is estimated to be as high as 33.7%, and generalized anxiety disorder is estimated to be 9%. Additionally, the World Health Organization estimates the global prevalence of anxiety disorders at 3.4% (World Health Organization, 2017). This large percentage affects individuals, their families, and the community at large. In 2002 the economic burden of anxiety disorders was estimated to be over $42 billion per year, including medical costs and loss of work productivity (Wittchen, 2002), and has since risen to an estimated $56 billion (Chisholm et al., 2016). Previous research has highlighted several risk factors for developing anxiety disorders. While all major anxiety disorders are linked to genetic predisposition (Hettema et al., 2005), heritability is only part of the picture for anxiety disorders. Along with genetics, environmental factors also contribute to the development of an anxiety disorder. These can include life stressors such as childhood adversity, childhood sexual assault, or the loss of a significant family member through death or separation, all of which could contribute to an increased vulnerability to anxiety disorders (Hettema et al., 2005).

Concerning environmental factors, daily stressors could also contribute to level of anxiety. Past research has determined that over and above the impact of major life events, daily hassles—

small, annoying, but recurrent life demands—might be even more influential on an individual's mood and anxiety levels (Russell & Davey, 1993). Furthermore, recent research supports the idea that cumulative stress, such as daily hassles, is predictive of psychological disorders such as depression. Vinkers and colleagues (2014) investigated cumulative stress, daily hassles, childhood maltreatment, and major life events as indicators of major depressive disorder (MDD) later in life. This study not only supported the notion that cumulative stress is significantly related to MDD but also found that this relationship is influenced by a person's neuroticism (Vinkers et al., 2014). Specifically, Vinkers and colleagues found that cumulative stress was more predictive of depression in those who reported high neuroticism, suggesting that certain traits may predispose people to react to stress in a way that may lead to psychological disorders. As news exposure is a daily occurrence for most people and can often have a negative emotional tone, it may serve in a similar capacity to other daily stressors that contribute to cumulative stress.

With the rise in social media (e.g., networking sites, Facebook, Instagram, Twitter) use, there has been a growing interest in how the use of technology, particularly social media, affects mental health. In the United States, approximately 90% of young adults use social media, and the majority use social media at least once a day (Pew Research Center, 2015). Findings have been mixed regarding whether social media is a benefit or detriment to mental health and overall life satisfaction. Whereas some studies support social media use as a contributor to increased self-esteem and social connectedness, other research has indicated that more time spent on social media led to increases in depression and anxiety symptoms (Andreassen et al., 2016; Block et al., 2014; Kross et al., 2013; Lin et al., 2016; Woods & Scott, 2016, see Primack, 2017).

Primack and colleagues (2017) investigated the use of multiple platforms of social media in relation to overall well-being. The researchers found that, when adjusting for time spent on social media, both depression and anxiety scores were positively correlated with the increased number of social media platforms used (Primack, 2017). One explanation for this relationship is that the use of multiple social media platforms, similar to multitasking, produces comparable negative effects (Primack, 2017). Previous research supports multitasking's relationship to increased anxiety and depression levels (Becker et al., 2013). Given this, in our study, we incorporated the number of sources of current events—like newspapers, television programs, and websites—as a factor in calculating news exposure.

While social media's influence on mental health has been a popular topic in recent years, recent research has begun to tease apart the information to which people are exposed. Researchers addressed the non-social features of smartphone use in relation to depression, anxiety, and stress (Elhai et al., 2017). Elhai and colleagues (2017) separated smartphone use into social use and non-social use, with the latter category including news consumption and entertainment. They found that non-social smartphone use was related to anxiety levels; however, in disagreement with Primack (2017), they found that social smartphone use was inversely related to depression (Elhai et al., 2017). Notably, to examine the mental health impact of smartphone use, Elhai and colleagues (2017) used Mechanical Turk (MTurk) to recruit a large, diverse sample of participants. While they took a cross-sectional approach to investigate their variables, they did not examine the impact of news consumption on anxiety levels over time.

Other related research also supports the idea that exposure to news may be a possible risk factor for psychological problems. Much of the coverage of current events outlets tend to include reports of crimes and other violence. One study addressed the impact of violent images and found that frequency rather than the duration of exposure was more predictive of mental health distress (Feinstein et al., 2014). It is thus likely that people who are more

frequently exposed to current events coverage would be affected by violent or anxiety-provoking images that may contribute to distress.

Notably, whereas almost everyone is exposed to current events to some extent, people can control their exposure by seeking out or avoiding particular news outlets. Valentino and colleagues (2009) found that, in general, there is a relationship between having a tendency for information seeking and anxiety levels. However, the reason for seeking information mattered. Specifically, their research found that information seeking that leads to the answer of an anxiety-provoking topic could resolve anxiety; however, superfluous information that does not lead to the resolution of a problem may cause further anxiety (Valentino et al., 2009). As news reports often present negative, anxiety-provoking information that does not necessarily resolve questions, the news could cause increases in anxiety. In fact, studies examining this cognitive style, called perseverative thinking, have found that nonclinical populations have lower scores on negative perseverative thinking compared to those diagnosed with depression or anxiety disorders (Ehring et al., 2011).

People who have difficulty managing their emotions and tolerating the uncertainty of daily life may be particularly vulnerable to the negative effects of news exposure. Thus, it is important to address whether excessive news exposure is a particular problem for those who have poorer emotion regulation ability. Emotional regulation is a range of activities, including the ability to self-monitor, interpret, and alter internal and external emotional expressions in an effort to respond to environmental demands in an appropriate manner (Klemanski et al., 2017). Klemanski and colleagues (2017) found that adolescents who had increased social anxiety and symptoms of depression self-reported less emotional awareness and decreased emotion management strategies. This finding supports Gross's (1998) original framework suggesting that difficulties in emotion regulation could sustain disorders such as anxiety. One way to capture emotional regulation is through intolerance of uncertainty (IU). Previous research has established that intolerance of uncertainty is related to anxiety disorders, with the majority of research supporting IU's relationship specifically to generalized anxiety disorder (GAD) (Boswell et al., 2013).

As a major component of GAD is worrying, research shows that worrying may be a function of lower psychological flexibility described as experiential avoidance (Hayes et al., 2004). For instance, those who take part in experiential avoidance — avoidance of emotions, thoughts, physical sensations, memories, and so on — may have more difficulty with the uncertainty of news, and this type of incomplete information could induce greater anxiety (Hayes et al., 2004). If a person has previously watched the news and experienced anxiety, they might categorize news as an experience worth avoiding in the future, and therefore be more distressed when exposed to it without seeking it. Previous research indicates that perseverative thinking – repetitive thinking – is common in those with GAD and leads to further distress (Ruscio et al., 2015). However, this relationship may be maintained in those with no previous or current psychopathology. Ruscio and colleagues (2015) found that even among nonclinical populations, those who engaged in perseverative thinking experienced worse outcomes than those who did not (Ruscio et al., 2015). As this study focuses on the general population, stress induced by information or news specifically could affect those who ruminate more so than those who do not.

The Present Study

Although the impact of social media on mental health has been examined in prior research, there is little literature that addresses the possible effects of chronic news exposure. To tease apart participant exposure to varying types of information, we created a study-specific questionnaire to ask about news behaviors. This questionnaire differentiated between social media and current event exposure. We also asked about accessing news,

sources, reasons for seeking, avoidance and seeking behavior, and enjoyment from the news. We made these various distinctions to better understand what aspects, if any, of news exposure impacted the psychological well-being of participants and to understand any moderators of this relationship.

This is an important area of research, given that people have more formats to access news today than ever before and that the news often reports negative or distressing information. This study examined the relationship between news exposure and psychological distress. Similar to Elhai and colleagues (2017), we used Mechanical Turk to survey a large sample of adults over three waves over three months. Given the existing literature on the impact of daily hassles and social media use, we hypothesized that greater news exposure would predict higher anxiety levels concurrently and prospectively but that the use of more adaptive emotion regulation strategies may serve as a protective factor.

The current study had three main aims. The first aim was to establish if there is a relationship between news exposure and anxiety levels by using a cross-sectional approach with the data from the first time point. The second was to evaluate whether anxiety levels changed over time in relation to news exposure. By using data from multiple time points, we were able to longitudinally evaluate whether anxiety levels changed over time in relation to initial news exposure. We expected that people with higher initial levels of news exposure would be more likely to experience increases in anxiety levels over time, as the news may have a cumulative impact as a chronic stressor. Our last aim was to establish if emotion regulation moderates these relationships. Specifically, we hypothesized that those who use more adaptive emotion regulation strategies (i.e., those who are more tolerant of uncertainty, are less likely to engage in perseverative thinking, and are more accepting of their experiences) would be less affected by the information they were exposed to, and their news exposure would be less predictive of their psychological distress. As news can create a sense of uncertainty about the world, as it often does not provide a full picture of a situation and creates doubts about safety, we hypothesized that those who have less tolerance for uncertainty would be more distressed when more exposed to the news. Similarly, we expected that those who experience more intrusive and repetitive negative thoughts, as well as those who tend to avoid unpleasant experiences, would be more affected by news exposure.

Method

Participants

We collected data from participants in three waves over three months. During Wave 1, 601 participants began our survey; however, 99 participants were excluded as they failed a simple inattention test (e.g., "please click 'Agree' for this item") or did not complete the survey in its entirety. Our final sample for Wave 1 was 502 participants (320 women, 181 men, and 1 participant who identified as intersex), with ages ranging from 18 to 77 years (*Mage* = 37.26 years, *SD* = 12.93). With regard to gender identity, 316 identified as female, 179 identified as male, three identified as transgender, one identified as intersex, and three chose not to identify. Of our sample, 26.1% described themselves as a student, while 15.3% reported being unemployed, and 67.8% worked at least 21 to 40 plus hours a week. For full demographics of Wave 1, see Table 1.

Procedure

Participants were recruited via TurkPrime, which utilizes members from Amazon's Mechanical Turk (MTurk). Once participants accepted our Human Intelligence Task (HIT) from TurkPrime, they were directed to complete a survey through a secure online data collection program called Qualtrics (Qualtrics, Provo, UT). During our initial recruitment phase, we had a bounce rate of 15% and a completion rate of 73%. The bounce rate was calculated based on how many people clicked on our survey description in MTurk and chose not to par-

Table 1

Demographics of Wave 1

Race (%)		
	Caucasian/White	80.1
	African American/Black	9
	Asian	8.6
	Latinx/Hispanic	5.8
	Multiracial	2
	Native American/Alaska Native	1.4
	Otherwise written in	1
	Native Hawaiian/Pacific Islander	0.4
	Middle-Eastern/North African	0.4
Marital Status (%)		
	Married	44.6
	Single	33.5
	Dating Seriously	10.8
	Divorced	7.6
	Engaged	3.8
	Dating Casually	3.4
	Widowed	2
Income (%)		
	<$15,000	9.6
	$15,000-25,000	14.3
	$25,000-35,000	14.7
	$35,000-50,000	14.7
	$50,000-75,000	10.2
	>$100,000	12.8
Education (%)		
	Some high school	8
	High school diploma/GED	12
	Some college	41.6
	Bachelor's degree	32.9
	Professional / Graduate degree	11.8

Note. Percentages for Race are greater than 100 as participants were able to select multiple responses.

ticipate in the study. The completion rate was the percentage of individuals who accepted the HIT and successfully submitted a code for compensation. For each of the three waves, the HIT consisted of an online informed consent, followed by a survey that included demographic information, a study-specific news exposure questionnaire that asked about current event news, as well as social media use, to gauge the level of information exposure, and questionnaires to understand participant's psychological distress and ability to regulate emotions. Once participants completed all the questionnaires in the survey, they were provided with a secret code to enter on MTurk to receive compensation.

We invited participants to complete our second and third waves via TurkPrime through their unique WorkerID, which allowed us to maintain their anonymity. All participants who completed Wave 1 in its entirety were included in the invitation lists for Wave 2 and Wave 3. On average, the waves were open for 16 days, with approximately a month in between each of the waves. Wave 1 participants were compensated $0.15, Wave 2 participants were compensated $0.35, and Wave 3 participants were compensated $0.50, for a total of $1.00 if participants completed all three waves. Notably, for the second and third waves, we sent reminder invitations before the close of the wave to those who were eligible to complete our study. Several participants provided helpful feedback on the survey, and we granted them an unannounced bonus ($0.50). After the third wave, we exported all the data into a format readable by the program Statistical Package for the Social Sciences (SPSS), which we used to analyze our data. Later in analyses, we used an SPSS macro program called ModText (http://davidakenny.net/dtt/moderate.htm), which allowed us to conduct and interpret interactions (Kenny, 2010). The Institutional Review Board approved all procedures.

Measures

News Exposure Questionnaire

To gauge how much information exposure our participants were receiving, we created our questionnaire based on prior studies of social media (see Correa et al., 2010), but instead focused on current events exposure to measure areas of news exposure, effort, and enjoyment. At each of our time points, we asked participants to reflect on the past week and answer about specific information exposure (see Appendix A for News Exposure Questionnaire). We asked on how many days of the past week they posted/read/listened to Facebook, Twitter, Instagram, News (i.e., current events), and how many times a day they accessed the news (e.g., once, two to three times, four to six times, or seven or more times). Social Media Use was calculated by the sum of Facebook use, Twitter use, and Instagram use. Information Use was calculated by summing Facebook use, Twitter use, Instagram use, and News use. We also broke down sources of current events exposure into different categories, including "morning/evening news programs (e.g., NBC, Fox News)," "entertainment news programs (e.g., TMZ, E! News)," "Newspapers (e.g., The New York Times)," "Radio Stations," "Social media (e.g., Twitter, Facebook)," "Websites (e.g., bbc.com)," and "Phone or tablet applications (e.g., Apple News, Flipboard)." We also asked participants to rank their preference order from the aforementioned sources from one (most preferred) to seven (least preferred). To measure participants' reason for news exposure, we asked why they accessed the news and provided them with the options "seek out specific information (e.g., to answer a particular question)," "to stay informed," "as part of my routine," and "to have things to talk about with others."

For analysis, we created three sum scores to understand the participants' experience with the news. News Exposure is a composite score that combined the variables of News Use, News Per Day, and News Types assessed by the questionnaire. News Effort was determined by the degree to which the participants sought out or avoided the news based on an 8-point scale, with the lowest

point representing "I avoided the news" and the highest point representing "I sought out the news." These scores were centered such that negative scores suggested "news avoidance" and positive scores suggested "seeking behavior." News Enjoyment was determined by the level participants reported enjoyment from the news based on a 5-point scale from one (none at all) to five (a great deal). The sum scores News Effort and News Enjoyment helped us to better understand participants' relationship in engaging with the news and their emotional response to News Exposure.

Psychological Distress

The Depression Anxiety Stress Scale (DASS-21; Antony et al., 1998) was used to evaluate participants' mental health with regard to depression, anxiety, and stress. The DASS-21 is a psychometrically validated questionnaire with advantages to the original 42-item version, including fewer questions, clearer factor structure, and a less inter-factor correlation (Antony et al., 1998). The DASS is scored on a 4-point scale from zero (never) to three (almost always), and the sums of respective scores can be doubled to compare to the extended DASS-42. The depression subscale consisted of seven items, including statements like "I found it difficult to work up the initiative to do things," and scores greater than nine are indicative of above normal. The anxiety subscale consisted of seven items, including statements like "I felt scared without any good reason," and scores above seven are considered above normal. The stress subscale consisted of seven items, including statements like "I tended to over-react to situations," and scores greater than 14 are considered above normal based on norms established by Antony et al. (1998). We calculated the internal consistency of the measure using Cronbach's alphas, which demonstrated good internal consistency for the total DASS-21 distress score ($\alpha = .96$), as well as each subscale: depression ($\alpha = .94$), anxiety ($\alpha = .89$), and stress ($\alpha = .91$).

Psychological Flexibility

Participants completed the Acceptance & Action Questionnaire-II (AAQ-II; Bond et al., 2004) to evaluate their propensity to accept or avoid experiences as a measure of psychological flexibility. While the AAQ-II measures the same concepts as the original AAQ-I ($r = .97$), it has better psychometric consistency (Bond et al., 2011). The AAQ-II contains seven questions and is scored on a 7-point scale from one (never true) to seven (always true). The seven items include statements like "I am afraid of my feelings" and "worries get in the way of my success." The scores of each question are usually summed such that higher scores indicate a lower level of psychological flexibility. For ease of interpretation, we reverse coded the scores such that higher scores presented greater acceptance (i.e., psychological flexibility). Notably, Bond and colleagues (2011) determined a 3- and 12-month test-retest reliability of .81 and .79, respectively. As our study is longitudinal, the test-retest reliability was important to our study. The measure showed good internal consistency in our study ($\alpha = .94$).

Intolerance of Uncertainty

The Intolerance of Uncertainty Scale (IUS; Carleton et al., 2007) was used to measure how well participants deal with ambiguity in daily life. This scale contains 27-items that require participants to rate themselves on a 5-point scale from one (not at all characteristic of me) to five (entirely characteristic of me) on items like "uncertainty stops me from having a firm opinion," and "unlike me, others always seem to know where they are going with their lives." Although some studies examine this scale based on separate factors where factor one measures items indicating the belief that "uncertainty has negative behavioral and self-referent implications," and factor two measures items indicating the belief that "uncertainty is unfair and spoils everything" (Sexton & Dugas, 2009) for the purpose of our study, we chose to use the total score of the IUS in analysis. This measure had good internal consistency in our sample ($\alpha = .97$).

Perseverative Thinking

Lastly, in the second and third waves of our surveys, we asked participants to complete the Perseverative Thinking Questionnaire (PTQ; Ehring et al., 2011) to provide information about how they typically think about negative experiences or problems. This questionnaire contains 15 items scored on a 5-point scale from zero (never) to four (always), with higher sums indicating thinking characterized as repetitive, intrusive, difficult to disengage from, unproductive, and occupying mental capacity. The PTQ includes items like "thoughts intrude into my mind" and "my thoughts repeat themselves." Notably, we also included an attention filter within this questionnaire ("please select 'always' for this item") to help identify inattentive participants and exclude them from analyses. This scale had good internal consistency for our sample ($\alpha = .97$).

Results

Preliminary Analyses

Of our original 502 participants at Wave 1, we had 304 (60.5%) complete Wave 2 and 305 (60.7%) complete Wave 3. Notably, 252 (50.2%) participants completed all three waves. We examined whether waves differed on important demographic variables. Between all waves, there were no statistical differences between waves with regards to gender (χ^2 (4) = .99, p = .911). However, there was a significant difference in ages between waves, $F(2, 1107) = 5.78$, p = .003, with a higher average age of participants at Waves 2 and 3 compared to Wave 1 (see Table 2 for participant characteristics). Furthermore, whereas gender was not

Table 2

Participants Characteristics by Wave

	Wave 1		Wave 2		Wave 3	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age	37.26	12.93	39.81	13.17	40.06	13.26
Gender (% Female)	62.9	-	64.5	-	66.6	-
News Exposure	10.73	4.39	11.04	4.25	11.54	8.01
News Effort	1.24	1.88	1.31	1.82	1.29	1.81
News Enjoyment	3.25	1.11	3.24	1.13	3.28	1.14
Social Media Use	7.96	5.34	8.12	5.52	8.19	5.51
DASS Depression	5.51	5.84	4.96	5.67	4.99	5.69
DASS Anxiety	4.02	4.59	3.59	4.39	3.92	4.46
DASS Stress	6.06	4.85	5.82	4.70	6.02	4.93
Acceptance	33.99	11.56	34.38	11.16	34.59	11.50
IUS	66.05	26.41	67.12	24.65	66.48	25.61
PTQ[a]	-	-	27.29	14.34	28.40	14.52

Note. DASS = Depression Anxiety Stress Scales; IUS = Intolerance of Uncertainty Scale; PTQ = Perseverative Thinking Questionnaire. [a]The PTQ was only administered in Waves 2 and 3.

related to any of our outcome variables of interest (all *p*-values > .46), we determined that age correlated with the majority of our variables. Older participants tended to have lower depression, anxiety, and stress as indicated by participants' subscores on the DASS, as well as lower scores on the IUS and reported lower Social Media Use (all *r*-values < -.28, $p < .01$). Older participants also reported higher News Use, News Exposure, News Effort, News Enjoyment, and psychological flexibility (i.e., experiential acceptance) (all *r*-values > .25, $p < .01$). Thus, we controlled for age when testing our hypotheses about the relationship between news exposure and psychological distress.

Participants' Information Use and Preferences

The following data was captured by the News Exposure Questionnaire. Our participants frequently took part in watching, hearing, and/or reading about the news, which we categorized as current events news. Of our 502 participants, 77.5% engaged in the news a minimum of four days a week, and 45.2% engaged with current event news every day in the week. Of the participants who accessed the news, the majority (70.6%) accessed the news multiple times a day. We asked participants in the past week the sources they used to access the news and reported the following: social media (63%), websites (63%), morning/evening news (53%), newspapers (26%), radio stations (26%), phone or tablet applications (19%), entertainment news (16%), and did not access the news (2%). Percentages do not add up to 100% as participants could choose multiple sources. When asked to rank news platforms based on preference, their top preference was as follows: morning/evening news programs (32%), websites (31%), social media sites (18%), newspapers (7%), radio stations (5%), phone or tablet applications (4%), and entertainment news (2%). With regard to motivation for accessing the news, participants were most likely to report seeking out the news to stay informed (40%), followed by the news being part of their routine (32%), then to seek out a specific answer (21%), and lastly to have points for conversation (10%). When asking about social media, participants reported accessing the following platforms at least once in the past week: Facebook (85.7%), Twitter (49%), and Instagram (44.2%).

Along with asking what information participants engaged with, we asked our participants to describe the most recent news event they remembered hearing or reading about. Of the 300 responses, 270 (90%) reported negative events (i.e., deaths of celebrities, worries about security, and political uncertainty). Of the remaining responses, only 2.6% were positive events (i.e., a woman helping an animal shelter), with the remaining 7.3% reporting neutral or factual information (i.e., an article about football). While this information may not proportionally represent events reported in the news, it does depict what is most salient in our participants' memory. From our results, it appears that negative reports are what leave a lasting impression on those who engage with the news.

Does News Exposure Relate to Psychological Distress?

To address our first aim of establishing if there is a relationship between news exposure and anxiety, we conducted concurrent analyses using partial correlations that controlled for age. As expected, all our information and news-related variables significantly positively correlated, and all psychological distress variables were significantly positively correlated (all *p*-values < .001; see Table 3 for correlations of measures of Wave 1 controlling for age). Although we did not find a significant direct correlation between news exposure and anxiety levels, those who were more anxious (higher DASS Anxiety scores) reported higher intolerance of uncertainty ($r = .54$, $p < .001$), and perseverative thinking ($r = .49$, $p < .001$), and lower psychological flexibility, i.e., Acceptance ($r = -.59$, $p < .001$) suggesting experiential avoidance.

In addition to addressing our main variable of interest, anxiety, we also looked at the relationship between news exposure and depression

Table 3

Correlations of Measures at Wave 1 Controlling for Age

Measures	1	2	3	4	5	6	7	8	9	10
1. Information Use	-									
2. News Exposure	.49***	-								
3. News Effort	.36***	.53***	-							
4. News Enjoyment	.25***	.38***	.64***	-						
5. Social Media Use	.94***	.24***	.20***	.14**	-					
6. DASS Depression	-.09*	.03	-.06	-.09†	-.09†	-				
7. DASS Anxiety	-.03	.03	.04	-.02	-.003	.66***	-			
8. DASS Stress	-.05	.02	-.02	-.09*	-.04	.77***	.74***	-		
9. Acceptance	.03	-.02	.07	.14**	.01	-.74***	-.59***	-.65***	-	
10. IUS	-.01	.02	.02	-.004	-.006	.60***	.54***	.63***	-.67***	-
11. PTQ[a]	.04	.08	-.08	-.09	.04	.68***	.49***	.70***	-.75***	.69***

Note. DASS = Depression Anxiety Stress Scales; IUS = Intolerance of Uncertainty Scale; PTQ = Perseverative Thinking Questionnaire.
[a]The correlations with PTQ were calculated at Wave 2, since the measure was not administered during Wave 1.
†$p < .06$ * $p < .05$. ** $p < .01$. *** $p < .001$

and stress as measured by the DASS. We looked at these additional variables to understand if news exposure had potential relationships not previously considered. Depression levels either approached significance or had weak significant correlations with Information Use, Social Media Use, and News Enjoyment (p-values < .06). Those with higher depression scores based on the DASS reported lower frequency of Information Use (r = -.09, p = .044), lower Social Media Use (r = -.09, p = .510), and less News Enjoyment (r = -.09, p = .052). Additionally, participants who were more depressed tended to have higher intolerance of uncertainty (r = .60, $p < .001$), perseverative thinking scores (r = .68, $p < .001$), and lower psychological flexibility, i.e., Acceptance (r = -.74, $p < .001$). Lastly, stress levels as determined by DASS scores had a significant correlation with News Enjoyment, such that those who enjoyed the news less were more stressed (r = -.09, p = .049). Although stress did not significantly correlate to our other news variables (i.e., News Exposure and News Effort), those who reported higher stress reported higher intolerance of uncertainty (r = .63, $p < .001$), perseverative thinking scores (r = .70, $p < .001$), and lower psychological flexibility, i.e., Acceptance (r = -.65, $p < .001$).

Does News Exposure Change Over Time?

We conducted a Repeated-Measures ANOVA to determine whether the waves significantly differed on variables of interest. We found no significant differences on News Exposure [Wilks' Lambda = .982, $F(2, 250) = 2.27$, p = .106], News Effort [Wilks' Lambda = .997, $F(2, 250) = 0.36$, p = .700], or News Enjoyment [Wilks' Lambda = .998, $F(2, 250) = 0.26$, p = . 770] between the three waves. This suggests that participants' access to current events news was fairly stable over time. However, the analysis was significant for DASS Depression scores [Wilks' Lambda = .963, $F(2, 250) = 4.796$, p = .009]. A Bonferroni post hoc test indicated that the mean scores for Wave 1 (M = 5.51, SD = .368) were significantly higher than the scores for Wave 2 (M = 4.96, SD = 0.36) and Wave 3 (M = 4.99, SD = 0.36); Waves 2 and 3 did not significantly differ. On the DASS Anxiety and Stress subscales, there were no significant differences between any of the waves (all p-values > .05). In other words, our participants were significantly more depressed during Wave 1 as compared to the later waves, which may correspond to the timing of Wave 1 being close to the winter holidays along with its overlap with the 2016 presidential election.

Do News Variables Predict Changes in Mental Health Over Time?

To address our second aim, we ran Multiple Regression analyses, in which we controlled for age and the initial levels of the variables of interest. While running our regressions, we looked at news exposure, news enjoyment, and news effort simultaneously as possible predictors of psychological distress. Notably, initial levels significantly predicted later levels for all our variables of interest in these models (all *p*-values < .001). Additionally, multicollinearity was not a concern as all Tolerance levels were < 1 and all VIF levels were < 2.5.

Anxiety levels at Wave 2 and Wave 3 were not predicted by any of our Wave 1 news-related variables (*p*-values > .40). Neither were stress levels at Wave 2 or 3 (*p*-values > .60). However, controlling for News Exposure and News Effort as well as age and initial level of depression, News Enjoyment ratings significantly predicted the DASS depression scores at Wave 2 (b = -0.51, t = -2.23, p = .026). Notably, news variables did not explain a significant proportion of variance in Wave 2 depression scores above and beyond age and initial levels, adjusted $R2$ = .69 ($\Delta R2$ = .002, p = .550). This relationship was not maintained over the following month, with no significant news-related predictors for Wave 3 DASS depression scores (*p*-values > .30). In other words, those who receive more enjoyment from the news seem to have less depression over time in the short-term, but not long-term.

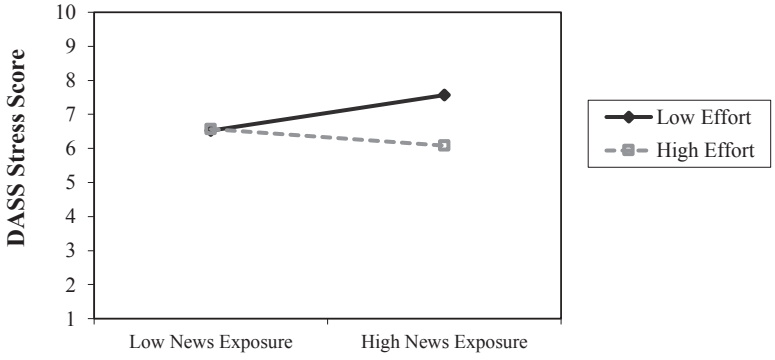
Both Wave 1 News Exposure scores (b = 0.57, t = 2.48, p = .014) and News Enjoyment scores (b = -2.26, t = -2.22, p = .270) significantly predicted IUS scores at Wave 3, though no news-related variables were significant for predicting Wave 2 IUS scores, when controlling for age and initial levels scores (*p*-values > .15). This suggests that those who are more exposed to the news or who enjoy the news less may, over time, have more difficulty tolerating uncertainty. Lastly, experiential acceptance and perseverative thinking changes were not significantly predicted by initial News Exposure levels (*p*-values > .06).

Does Emotion Regulation Moderate the Relationship Between News Exposure and Mental Health?

Our last aim was to establish if emotion regulation moderates potential relationships between news exposure and psychological distress. Although there was no significant direct relationship found between anxiety and News Exposure, we examined whether aspects of emotion regulation may interact with News Exposure in predicting psychological distress while controlling for age. We found a significant interaction effect of News Exposure x News Effort in predicting DASS Stress (b = -.08, R^2 = .01, p = .050). Figure 1 shows that participants who made a greater effort to seek the news and had higher News Exposure were less stressed than those

Figure 1

News Exposure and DASS Stress Moderated by News Effort



Note. DASS = Depression Anxiety Stress Scales. When controlling for age, we found that News Effort was a significant moderator of the relationship between News Exposure and DASS stress scores. Those who put in higher effort to seek the news and had high news exposure were less stressed than those who tended to avoid the news but also had high news exposure.

who tended to avoid the news but had high News Exposure. There were no significant interaction effects of News Exposure x News Effort on DASS Anxiety or DASS Depression scores (p-values > .40). Furthermore, News Exposure did not interact with News Enjoyment, psychological flexibility (i.e., experiential acceptance), intolerance of uncertainty, or perseverative thinking to predict any psychological distress variables (p-values > .25). Notably, when controlling for News Exposure in these analyses, higher levels of News Enjoyment predicted lower levels of stress (b = -.11, p = .024) and depression (b = -.11, p = .022), whereas greater tendency to avoid the news predicted higher levels of depression (b = -.13, p = .023).

Discussion

The study aimed to identify whether there is a link between news exposure and mental health factors such as anxiety, stress, and depression. Although we hypothesized that the frequency at which people are exposed to current events coverage would predict anxiety levels, we did not find a direct relationship between anxiety and news exposure. Information exposure appeared to be more relevant to participants' depression, as higher depression scores were related to less use of total information (including social media use and overall social media and current events use) and marginally less enjoyment of news. These relationships could be in part due to the relationship between social isolation and depression, as people with lower moods tend to withdraw and may have less energy to engage in information use, particularly social media, and tend to be less active in their social life (Elhai et al., 2017). One interpretation of these findings is that engaging in information exposure could be protective against isolation and depressive symptoms; however, it could also be that those who are not experiencing any depressive symptoms would be more likely to engage in daily routines such as keeping up with the news (Elhai et al., 2017).

As previously researched by Valentino and colleagues (2009), those who engage with more information use may be using that information to answer questions to resolve anxiety, or that information may simply fuel further information seeking. Consistent with this, we found that greater News Exposure and less News Enjoyment predicted more intolerance of uncertainty prospectively, controlling for initial levels. It may be that people who are seeking out the news but find it unpleasant experience increased difficulties coping with ambiguity over time, perhaps leading to an even greater focus on unhelpful and unpleasant information seeking. Given that we found depression, anxiety, and stress scores all positively correlated with intolerance of uncertainty and perseverative thinking in our sample, this pattern could be maladaptive over a longer period.

Whether participants identified as a 'seeker' or 'avoider' of the news also appears important to reactivity to the news. In our study, participants who reported the highest stress levels were those that had high levels of exposure to news and simultaneously wanted to avoid exposure to news. Notably, we found no other significant interaction effects. Similar to Valentino and colleagues (2009), it may be that those who seek out information are more so protected by the information when they make an effortful choice to engage in it.

Additionally, participants in our study who reported enjoying the news tended to have lower stress levels, somewhat lower depression, and greater psychological flexibility. Furthermore, over time, these people tended to be less likely to be depressed, controlling for initial levels of depression. Therefore, a willingness to learn about even unpleasant current events may be adaptive, as it demonstrates greater psychological flexibility as described by experiential acceptance.

Strengths and Limitations

Although we were specifically interested in the relationship between information exposure and anxiety, we used multiple measures to create a fuller picture of how information affects mental

health. Since there is no established measure for news exposure, we created our own. However, when creating this measure, we kept in mind previous research that measured similar constructs, such that our news and information behavior questions were adapted from research on social media exposure (Correa et al., 2010). In addition, our other measures of psychological distress and emotional regulation were psychometrically sound, with strong reliability, and were well established.

Through our use of MTurk and Turk Prime for recruitment, we were able to gather a more diverse sample rather than using undergraduates or other more homogenous samples. By using a sample of adults from the general population, as opposed to targeting a college population or treatment-seeking clinical population, we increased our variability. Using only students might have biased our results, as college students may not engage with news exposure as regularly as the general adult population and are generally more distressed (Sharp & Theiler, 2018). Moreover, if we sampled a clinical population, we would have only learned about those at the high end of anxiety symptoms. However, it is important to note that our study began around the 2016 presidential election, which could have impacted our concurrent results at Wave 1.

Despite our sample having diverse socioeconomic, gender, and relationship status backgrounds, the majority of participants identified as White, and all had to be familiar with computers to access the survey, suggesting a certain minimum education level. Although our sample had more females (62.74%), gender did not appear to influence any of our factors. Since age influenced our measures, we controlled for this influence in our final analyses.

As our study was longitudinal, we planned for attrition and therefore began by recruiting a large sample. Notably, about half of these participants completed all three waves, allowing us to look at their experiences over time. We tried to minimize attrition by recruiting experienced users and informing participants initially that this would be a longitudinal study where they would be contacted again if eligible. In future studies increased compensation, and more consistent reminder e-mails could increase retention. Since our News Exposure Questionnaire was self-report, our participants might not have provided the most accurate account for how much information they engaged with and were exposed to, as participants may have wanted to manage impressions by over-reporting news engagement. Future studies could require participants to keep a more detailed log to ensure correct information.

An additional improvement for future studies could include a more specific reporting of news sources. Specifically, participants could be asked about their specific sources of news information, as providers of the news are often politically aligned, and those who engage in the news that matches their own beliefs may be less distressed than those who expose themselves to multiple news sources that may challenge their beliefs. Along with our findings, it could be that those who are more psychologically flexible (i.e., endorse experiential acceptance) engage with challenging beliefs but are better able to cope than those who are not as flexible (i.e., endorse experiential avoidance). This would be another interesting area to explore in future studies.

Lastly, a major limitation of this study is that it was entirely conducted online, a procedure that can lead to questions of validity. To maximize the quality of our data, we limited potential participants to those who had previous experience with MTurk. Specifically, we required our participants to have a prior HIT Approval Rate of 90-100% and were required to have completed at least 100 prior HITs. Additionally, since our data collection consisted of multiple surveys, we included multiple attention measures to ensure participants were not thoughtlessly clicking through our measures. As our participants were compensated through MTurk, only participants who completed all measures and successfully attended to our attention filters were in-

cluded in our analysis.

Implications and Future Research

Although our findings did not support our predictions about news exposure and anxiety levels, we found that some news-related variables predicted psychological distress. This study highlights a future area of research on this potential chronic stressor. Future studies might sample a clinically anxious or depressed population to examine whether those who have an anxiety or depressive disorder are more influenced by superfluous information exposure. For example, those who take part in more perseverative thinking may benefit more from an information exposure intervention rather than the general population. Since news exposure was not a daily hassle for everyone in this study, rather only those who also tended to try to avoid the news, this study highlights that chronic stressors may affect those individuals differently, like those predisposed to stress. If information exposure does pose more detriment to those with mental health disorders, this may be an area important for clinicians to assess before or during psychotherapeutic treatment.

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Appendix A

News Exposure Questionnaire

How many days out of the <u>past 7 days</u>, did you post on Facebook or read any updates from people you know?

1 2 3 4 5 6 7

How many days out of the <u>past 7 days</u>, did you post on Twitter or read any updates from people you know?

1 2 3 4 5 6 7

How many days out of the <u>past 7 days</u>, did you post on Instagram or look at any updates from people you know?

1 2 3 4 5 6 7

How many days out of the <u>past 7 days</u>, did you watch/hear/read about the news (current events)?

1 2 3 4 5 6 7

<u>In this past week</u>, on days that you did access the news, how many times per day (on average) did you watch/hear/read about the news?

Once per day

2-3 times

4-6 times

7 or more times

I did not access the news at all

<u>In this past week</u>, where did you get your news information? (Check all that apply)

Morning/evening news programs (e.g., FOX news, NBC)

Entertainment news programs (e.g., TMZ, E! News)

Newspapers (e.g., The New York Times)

Radio stations (e.g., NPR)

Social media (e.g., Twitter, Facebook)

Websites (e.g., bbc.com)

Phone or tablet applications (e.g., Apple News, Flipboard)

I did not access the news at all

Please order the following list in terms of your preference for receiving news information (1 being most preferred 7 being least preferred)

Morning/evening news programs (e.g., FOX news, NBC)

Entertainment news programs (e.g., TMZ, E! News)

Newspapers (e.g., The New York Times)

Radio stations

Social media (e.g., Twitter, Facebook)

Websites (e.g., bbc.com)

Phone or tablet applications (e.g., Apple News, Flipboard)

Thinking about this past week, how much did the following statements apply regarding your decision to access the news? (Check all that apply.)

	Does not describe me at all (1)	(2)	(3)	(4)	(5)	Very much describes me (6)
I accessed news to seek out specific information (e.g., to answer a particular question).						
I accessed the news to stay informed.						
I accessed news as part of my routine.						
I accessed the news, because I wanted to have things to talk about with others.						

How much do you make an effort to access the news/recent events?

(1) Strongly AVOID the news
(2)
(3)
(4)
(5)
(6)
(7)
(8) Strongly SEEK OUT the news

How much do you enjoy reading/hearing/watching the news?

(1) A great deal
(2) A lot
(3) A moderate amount
(4) A little
(5) None at all

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