Investigating the relationship between meta-Cognition and Political Extremism

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Declaration

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Summary

The aim of this study was to investigate whether political extremism is associated with fundamental differences in perceptual decision-making, metacognitive awareness, and their underlying neural mechanisms. Previous research suggests that politically extreme beliefs are linked to overconfidence, cognitive rigidity, and reduced sensitivity to disconfirmatory evidence (Fleming & Daw, 2017; Rollwage et al., 2018; Zmigrod et al., 2019; Rollwage et al., 2020). Yet, most existing studies have used behavioral measures alone, leaving the neural processes related to these effects largely unexplored. Understanding these neural differences is important, as they can influence behavior and decision-making in politically charged contexts. The centro-parietal positivity (CPP), a neural correlate of decision formation, has been identified in the human EEG (Kelly & O'Connell, 2013; O'Connell, Dockree & Kelly, 2012), providing an unprecedented opportunity to measure its sensitivity across more extreme versus more moderate participants. In doing so, the current study aimed to bridge the gap between behavioral and neural measures of extremism. More specifically, this thesis investigated evidence accumulation and metacognitive processes across political divides. Using EEG, the project examined how Moderates and more extreme individuals accumulate evidence, process feedback, adapt their beliefs, and differ in error awareness and metacognition.

Fifty-seven participants were recruited from the general population and divided into more moderate and more extreme groups based on a validated pre-screening scale. Each individual carried out a random dot motion direction discrimination task (Kelly & O'Connell, 2013; Grogan et al., 2023), in which they reported their perceptual choice and their confidence, under conditions with and without external feedback. Behavioral measures included accuracy, reaction time, confidence ratings, metacognitive efficiency, changes of mind, and post-error adjustments. Neurally, the study focused on examining evidence accumulation (CPP) between groups in stimulus-, response-, confidence-response-, and feedback-locked epochs.

The overall task performance was better in Moderates than Extremists: Initial decision accuracy was slightly higher in Moderates. Extremists did not show greater cognitive rigidity, reduced

metacognitive efficiency, or faster decision-making. Extremists were actually slower in their initial decisions, suggesting a more cautious decision style or poorer encoding of evidence. Both groups showed similar post-error slowing and changes of mind. Behavioral results showed slight improvements in accuracy in Extremists when feedback was provided which highlights that their sensitivity to feedback is not fundamentally impaired but eventually context-dependent. Importantly, Extremists did show significantly higher confidence levels than Moderates across both feedback conditions and error trials. Overall, neural evidence accumulation dynamics were similar between Moderates and Extremists despite the observed behavioural differences. Feedback-related analyses showed significant decreases in confidence-locked evidence accumulation in Extremists. Otherwise, the study did not find reliable group differences in neural responsiveness.

Our findings do not show any significant fundamental differences in early perceptual evidence accumulation since the CPP dynamics were similar across participants. However, we observed an interesting pattern: more extreme participants were consistently more confident, and their CPP amplitudes were slightly higher, even though they showed lower decision accuracy and slower response times. This dissociation suggests that extremism may be linked more to how evidence is evaluated and translated into confidence and behavioral responses. These results point toward differences in post-perceptual, top-down evaluative processes, such as the weighting, interpretation, or maintenance of accumulated evidence. In this sense, ideological differences could emerge from the subjective evaluation of decisions. To validate early perceptual mechanisms differences, future research requires replication with a larger and more extreme sample. While our findings require further investigation, they also highlight the importance of future research examining the mechanisms that link sensory evidence to confidence judgments and decision behavior in politically extreme individuals.

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CPP	Centro-parietal positivity
EEG	Electroencephalography
ERP	Event related potentials
fMRI	Functional magnetic resonance imaging
MEG	Magnetoencephalogram
RDM	Random dot motion task

Chapter 1: Introduction

1.1 General Introduction

Since the early 20th century, researchers have investigated how authoritarianism and xenophobia develop and how people with strong political opinions - political Extremists - differ psychologically from people with moderate views. In an uncertain and polarized political climate, ideological divisions can grow and increasingly impact personal relationships, societies, and policies. While most research has focused on the social, demographic and economic factors that make people vulnerable to radicalization, cognitive and decision making processes are underexplored. Traditionally, political extremism has been related to deep-seated beliefs and external factors, but recent research highlights the role of internal cognitive mechanisms such as meta-cognition and cognitive rigidity. Meta-cognitive awareness refers to the ability to evaluate and adjust one’s own cognitive processes and can moderate vulnerability to extremist ideologies (Rollwage et al., 2018), while cognitive rigidity can predict resistance to belief change despite contradicting evidence (Zmigrod & Goldenberg, 2021). Meta-cognitive awareness is important to theories of decision making, learning, and self-regulation. In 1987, Flavell introduced metacognition and inspired many researchers to investigate the concept further since. Research distinguishes meta-cognitive awareness between two main components: meta-cognitive knowledge, which describes the awareness of one's cognitive processes, and meta-cognitive regulation, which concerns the ability to control and modify cognitive strategies (e.g., Brown, 1987 ; Efklides, 2001; Flavell, 1987 ; Jacobs & Paris, 1987 ; Schraw & Moshman, 1995 ; Tanner, 2012). Within decision-making theories, higher meta-cognitive awareness is thought to support more effective choices, because it allows us to monitor and adjust cognitive strategies by enabling error monitoring and strategic adjustments (Yeung & Summerfield, 2012). In the neuropsychological literature, cognitive rigidity is defined as the inability to adapt to new or changing environments and a difficulty to switch between modes of thinking (Zmigrod, 2020). It is characterized by persistence with previously established rules, mental heuristics, or behavioural patterns (Ionescu, 2012).

Early work has looked at the cognitive roots of extreme behavior, highlighting mental rigidity - such as inflexible thinking processes and intolerance - as a cause of ideological attitudes (Rokeach, 1948). This aligns with empirical research by Adorno and his colleagues (Adorno et al., 1950) who found prejudice to be related to cognitive rigidity. In “The Authoritarian Personality” (1950), one of Adorno’s colleagues found that children with higher prejudice scores also showed greater rigidity in perceptual and arithmetic tasks, compared to children who had lower prejudice scores. While these findings established a connection between ideological and cognitive rigidity early on, modern theories refocused on social and motivational explanations for extremism. For instance, feelings of meaninglessness and anxious uncertainty could drive individuals toward extreme ideologies to find structure and significance (Van Prooijen & Krouwel, 2019). This aligns with the Terror Management Theory which claims that existential anxiety, especially the awareness of one’s own mortality, motivates people to cling more strongly to cultural and ideological beliefs as a defense mechanism (Pyszczynski, Greenberg, & Solomon, 1999). More recently, several studies have reported that extreme individuals show higher cognitive inflexibility rather than reflective thinking (Zmigrod et al., 2019), alongside traits such as cognitive simplicity, overconfidence, and psychological distress (Van Prooijen & Krouwel, 2019).

To date, however, empirical research in cognitive neuroscience and psychophysiology that could elucidate the neural underpinnings of these behavioural differences remains very limited. Investigating neural and behavioral mechanisms can provide a complementary perspective by addressing questions such as: How do decision-making processes differ between Moderates and Extremists? Do thresholds for making a decision vary, and is the accumulation of evidence or metacognition different across groups? How aware are Moderates versus Extremists of their own errors? How well do they adapt to feedback in simple perceptual decision-making tasks?
Studying these mechanisms not only fills gaps in understanding cognitive processes that underlie extremism but also has implications for experimental and decision-making neuroscience, by identifying how belief-driven biases may affect perception, evidence accumulation, metacognition and neural signatures. Therefore, the current study focuses on the neural mechanisms, metacognitive awareness, and differences in electroencephalogram (EEG) signals between more

moderate and more extreme individuals - an approach that, to our knowledge, has not been undertaken in this format to date.

Studying the neural underpinnings of extreme individuals can also clarify the extremist mindset, including why extreme movements emerge during crises and why moderate parties in the EU (e.g., in Germany) have lost support while far-left and far-right parties have gained in the current politically uncertain climate (see Germany's Elections in 2025). Such research is therefore highly relevant for policymakers and institutions addressing the rise of extremism, the erosion of democratic norms and growing political polarization.

Understanding the cognitive and emotional motivations behind individuals' alignment with extreme ideologies can inform interventions to build a more cohesive, moderate, and tolerant society. For people with high cognitive rigidity and low metacognitive awareness, future research may also explore training methods to enhance metacognitive abilities such as self-awareness and to reduce rigidity, driving radicalization. Investigating the cognitive and neural drivers of political extremism also has implications for education, critical thinking, and expert judgment in fields such as law, national security, and clinical psychology, where identifying markers of risk can improve public safety.

This chapter introduces the theoretical frameworks that underlie the current study on perceptual decision-making and its neural mechanisms in moderate versus more extreme participants. First, it reviews metacognition, cognitive rigidity, and feedback, which are directly relevant to my study, as previous research highlights their role in political cognition and extremism. Next, the focus shifts to cognitive psychology and neuroscience literature on extremism more generally. Finally, the review turns to electroencephalography (EEG) and its potential to offer a more cohesive understanding of the political mind—particularly through the investigation of the centro-parietal positivity (CPP). The chapter will conclude by outlining the current study and by highlighting its objectives and methodology in relation to these theoretical concepts.

1.2 The Psychology and Neuroscience of Political Extremism

1.2.1 General

Research in cognitive psychology and neuroscience on political extremism has investigated a range of potential contributors, including cognitive traits, structural brain differences, and vulnerability to biased information processing. Individuals prone to extremist ideologies tend to show cognitive caution, slower perceptual processing, weaker working memory, and impulsivity linked to sensation-seeking and risk-taking. More specifically, evidence suggests that ideological worldviews could reflect low cognitive and perceptual functioning (Zmigrod, et al. 2021). Other studies have highlighted stress-related neurochemical changes, which can increase the susceptibility to simplified and radical messages by shifting cognition from deliberative reasoning to habitual responses. This "threat-based neural switch theory" may explain how stress arising from economic crises can alter brain processes and make individuals vulnerable to oversimplified, often extreme, political messages (Németh, 2024). Additionally, structural brain differences have also been linked to political orientation: studies found a slightly larger amygdala in conservatives which is an area associated with threat and fear processing (Kanai et al., 2011). Nevertheless, literature on radicalization claims that Extremists on both ends, left- and right-wing, share psychological features mostly (Kruglanski et al., 2014), including distress, cognitive simplicity, overconfidence, and intolerance (Van Prooijen, 2019).

Together, most findings to date led to a more static and trait-based understanding of political extremism. While these are informative for personality-driven and neurostructural models of the "extreme" mind, such research offers limited insight into dynamic cognitive processes like belief updating and decision formation. In contrast, decision-making neuroscience is process-oriented, as it tracks choice formation over time. Moreover, the field has developed paradigms that make it possible to disentangle behavioural and neural markers of meta-cognition, cognitive rigidity, uncertainty monitoring, and confidence-performance calibration across the stages of neural decision-making. Research using these paradigms has shown that metacognition and cognitive rigidity can have effects on learning, confidence judgments, and belief revision (Stanton et al., 2021; Fleming, 2024) and are relevant to understanding ideological attitudes (Zmigrod et al., 2019; Zmigrod et al., 2021).

Before turning to the background literature on psychological theories of political extremism, it is important to highlight that political extremism involves a spectrum of cognitive and affective processes shaped by both individual and social context. Even though extremism cannot be reduced to the basic decision making processes of individuals, including metacognition and cognitive rigidity, previous studies' focusing on stable traits and neurostructural correlates overlook how (extreme) decisions are formed, maintained, and revised. The current study, using perceptual decision-making neuroscience, addresses this gap by investigating ideological extremism in dynamic cognitive processes. Nevertheless, the following sections will situate this approach within the broader psychological literature, reviewing relevant theories (1.2.2).

1.2.2 Personality and Societal Theories of Extremism

Political extremism can be understood through several psychological theories that address the cognitive, emotional and neural mechanisms underlying ideological action. The significance-quest theory states that people radicalize to fulfill their need to feel important (Kruglanski et al., 2014). Stressful personal or societal events, such as injustices or economic crises, can drive people to regain a sense of purpose by following well-defined ideological convictions (Webber et al., 2018). A related theory, the Uncertainty-Identity Theory, argues that feelings of uncertainty motivate individuals to identify with groups as a way to regain stability. In fact, this theory is relevant to explaining extremism, as individuals seeking group identification often do so because it provides a predictable environment where they have a clear sense of identity and direction - knowing who they are, what to think, and how to feel (Hogg, 2012).

Similarly, the social identity theory explains how individuals categorize themselves into different social groups to construct their own social identity (Hogg & Reid, 2006). This process can lead to violent behavior when personal and group identities become fused, and individuals feel threatened in their social identity (Hogg & Reid, 2006; Echelmeyer et al., 2023).

To explain why some people are more likely to follow these ideologies than others, the cognitive rigidity theory suggests that some people struggle to mentally adapt to new information and are more prone to ideological extremism, partisanship, and dogmatism (Zmigrod et al., 2020).
The Authoritarian Personality Theory further examines the psychological features of individuals who unquestioningly obey authority figures. These individuals have a strong need for leadership and they tend to follow a black-and-white worldview, a framework that is also historically applied to explain the rise of the Nazi regime in Germany (Adorno et al., 1950).

Lastly, the Terror Management Theory gives an evolutionary and social psychological perspective on extremism. According to this theory, the fear of death drives individuals to adopt worldviews that enhance their self-esteem, provide meaning, and reinforce their sense of worth, which can contribute to extreme behavior and hostility (Weise et al., 2008).

Taken together, psychological theories of extremism explain the cognitive, emotional, and social mechanisms which underlie radicalization. They help explain why individuals adapt extreme beliefs, how they respond to uncertainty, and what psychological features increase vulnerability to extremism. In addition, these theories will make it possible for researchers to model pathways that lead to extremism, from identity formation and motivational processes to cognitive biases. They further allow the identification of potential interventions that could mitigate extremist behavior, such as increasing cognitive flexibility or reducing existential anxiety.

The main difference between these psychological theories on political extremism lies in their primary focus. Some emphasize individual cognitive traits (e.g., cognitive rigidity, authoritarian personality theory) whereas others highlight social and existential influences (e.g., significance quest, uncertainty-identity theory). While certain approaches focus on personality factors or neurocognitive mechanisms, others look at context-dependent processes, such as group dynamics and reactions to perceived threats.
Although these theories provide compelling explanations for radicalization and testable hypotheses, they may oversimplify complex ideological processes by underestimating the interaction between

cognition, neurophysiology, and social structures. Many psychological theories focus on broad trait-based explanations, which may fail to account for the dynamic and context-dependent nature of ideological shifts.

Despite these limitations, the reviewed theories join the idea that political extremism arises from psychological vulnerability and environmental influences. Central features include intolerance of ambiguity, need for certainty, and the role of identity in shaping ideological commitment.

1.3 Cognitive mechanisms relevant for the present study

Neuroscientific views on belief formation and decision-making suggest that extremism is not solely based on stable personality traits or social identity, but may also arise from differences in fundamental neurocognitive processes such as meta-cognitive awareness, confidence calibration, error monitoring, cognitive flexibility and belief updating. Accordingly, decision neuroscience frameworks have been applied increasingly to political extremism, especially in relation to meta-cognition and cognitive rigidity. For instance, studies on individuals with radical beliefs have found that low metacognitive scores are associated with extremism (Osorio & Reyes, 2025) and that cognitive inflexibility correlates with greater decision confidence in radical behavior (Zmigrod et al., 2019). Likewise, research on perceptual decision-making shows that, even when performing tasks that are stripped of any political or social content, individuals with rigid political ideologies are less adaptable to new information and that they show greater resistance to update their confidence when receiving corrective feedback (Rollwage et al., 2018). The following section will therefore cover the cognitive mechanisms that are relevant for the present study.

1.3.1 Measuring Metacognition

The literature below will highlight the role of metacognition in monitoring one's own successful cognitive processing, specifically in a perceptual decision-making task such as those used in the present study. The question that remains open is: how do we measure metacognition?

One way to measure how well individuals evaluate their own performance is to examine how closely a participant's confidence matches their actual accuracy. For example, a participant who is usually more confident when correct and less confident when they are wrong has good metacognitive sensitivity. Metacognitive sensitivity refers to how good one is at distinguishing between one's own correct and incorrect decisions (Fleming & Lau, 2014). Researchers use simple correlation measures, such as Pearson's r, to assess the association between accuracy and confidence and to quantitatively measure metacognition. Nevertheless, such a simple statistic is not always ideal due to response bias or other interfering factors. To address these limitations, more reliable measurements of metacognition include signal detection theory (which will be explained later in this Chapter under the "EEG" section), which accounts for bias. Moreover, SDT-based approaches also highlight distinctions within metacognition:

Metacognitive bias describes how confident a person is overall, regardless of their actual accuracy while metacognitive sensitivity explains how well someone knows whether they are right or wrong. And lastly, metacognitive efficiency refers to how good a participant's metacognitive sensitivity is, relative to their performance (Fleming & Lau, 2014).

The 2x2 confidence-accuracy table is a useful starting point for different measures of metacognitive sensitivity. This table counts how often people rate their confidence high or low in relation to whether their decision was actually correct or incorrect. When a person shows higher confidence for correct decisions compared to incorrect ones, it indicates above-chance metacognitive sensitivity. Again, this method is based on "type 2" signal detection theory, which focuses on confidence judgments about one's own responses rather than sensitivity to the external stimulus. Typically, task difficulty is kept constant to ensure that changes in confidence reflect internal evaluative processes, rather than changes due to task challenges (Fleming & Lau, 2014).

Now, the simplest association measures are the phi (ϕ) coefficient and Goodman–Kruskall gamma (G). Phi is just the regular correlation between whether a response was correct or not and whether confidence was high or low. Gamma is similar but works better when confidence is rated on a scale, not just high or low. However, both measures can be affected by metacognitive bias. This means that if someone tends to be generally very confident or very cautious regardless of how well they did, these scores might not accurately reflect their true meta-cognitive ability (Fleming & Lau, 2014). Some different measurements to counter these biases are the following:

Type 2 d′ is a signal detection theory (SDT) based measure of meta-cognitive sensitivity that tries to remove bias. It looks at how often people say they are confident when they are correct (hits) versus when they are wrong (false alarms). The calculation assumes that the internal signals for correct and incorrect decisions have the same shape and spread (Gaussian with equal variance). However, this assumption is usually not true for metacognitive judgments, which makes type 2 d′ less reliable because it can still be affected by bias (Fleming & Lau, 2014). Therefore, Type 2 ROC analysis offers a better solution by using a non-parametric approach that does not rely on strict assumptions about the data. It builds a curve (ROC curve) from confidence ratings across multiple levels, and it shows how well confidence distinguishes between correct and incorrect decisions. The area under this curve (AUROC2) measures metacognitive sensitivity without being influenced by bias or wrong assumptions about the data. However, even the AUROC2 can be affected by overall task performance, which means that changes in how well someone performs can influence it, even if their true metacognitive ability hasn't changed. Researchers have tried to control for this by keeping the task difficulty steady or modeling the relationship between performance and metacognition (Fleming & Lau, 2014).

The meta-d' measure is a new, improved model-based approach which links metacognitive sensitivity directly to type 1 performance (the actual task accuracy) (Maniscalco & Lau, 2012; Maniscalco & Lau, 2014). Meta-d′ estimates the amount of sensory evidence used for confidence judgments and expresses it in the same units as type 1 sensitivity (d′). For perfect meta-cognitive efficiency meta-d′ would have to be equal to d′. Deviations from this ideal are quantified by the ratio meta-d′/d′ or the difference meta-d′ − d′ and measure information loss during confidence formation, with values less than 1 indicating reduced meta-cognitive efficiency. Because it accounts for performance effects, meta-d′ is easier to interpret and more precise than other measures.

Despite these advantages, meta-d′ cannot distinguish whether lower metacognitive efficiency is due to variability in confidence criteria or from noise in the evidence supporting confidence judgments. The Stochastic Detection and Retrieval Model (SDRM) addresses this issue by modeling two sources of evidence: one for the decision itself and another one for the confidence rating. SDRM can explain dissociations between confidence and accuracy but it's more complex, so meta-d′ is often preferred for practical use (Fleming & Lau, 2014).

In fact, all these measurements above contribute to measuring metacognition in its various forms and serve as a baseline framework for understanding decision-making performance, confidence and judgment. Metacognitive bias, the tendency to give high confidence ratings regardless of whether the decision is right, can be measured by the percentage of high confidence responses or the average confidence rating. Metacognitive sensitivity can be measured by using psychometric functions which compare performance across different levels of task difficulty. One method looks at the difference in slope between performance curves for high- and low-confidence trials: steeper slopes for high-confidence responses suggest better metacognitive sensitivity. And lastly, metacognitive efficiency is measured relative to the performance level (Fleming & Lau, 2014).

Finally, there are also measures that assess metacognition by comparing a person's self-rating (e.g., "How good is your memory?") to their actual performance. While commonly used in clinical and social psychology, this one-time rating can't separate metacognitive bias (e.g., overconfidence) from sensitivity (actual insight into performance). In contrast, trial-by-trial data enables a more accurate analysis of bias, sensitivity, and efficiency, and will therefore be essential for this perceptual decision making study.

1.3.2 Meta-cognitive awareness in political cognition

Meta-cognition is studied across cognitive science, psychology, and neuroscience to understand how individuals monitor and control their own cognitive processes. The main difference between meta-cognitive frameworks is their focus. Some theories focus on knowledge, which highlights an individuals' understanding of their cognitive abilities and strategies. These include declarative knowledge (awareness of one's skills and limitations), procedural knowledge (how to use strategies), and conditional knowledge (when and why strategies are appropriate). However, regulation-focused perspectives highlight the active controlling of cognitive resources, such as attention and memory, to optimize task performance. This includes planning (goal setting and the allocation of resources), monitoring and evaluation (assessing performance and strategies), information management (organizing, summarizing, and elaborating information); and lastly, debugging, which allows checking for errors in performance (Schraw & Moshman, 1995). All of these different frameworks highlight the complex nature of meta-cognitive processes, some emphasizing knowledge and others focusing on regulation.

Metacognition is also important in a clinical context and linked to psychological disorders. Mental disorders, including psychosis-related symptoms, have been associated with a significant reduction in meta-cognitive sensitivity (Hohendorf & Bauer, 2023). Meta-cognitive biases, errors in how we think about our own thinking, are strongly linked to several psychological conditions, including anxiety, depression, and obsessive-compulsive disorder (OCD) (Seow, Fleming, & Hauser, 2025). These findings have informed metacognitive therapy (MCT), which is a treatment that focuses on changing maladaptive metacognitive beliefs. It is based on an information processing model that views these disorders as resulting from a “cognitive attentional syndrome” (CAS), which is caused by metacognitive impairments such as reduced flexible mental control. MCT aims to reduce these impairments. The theoretical foundation of MCT is the Self-Regulatory Executive Function Model by Wells and Matthews, which posits that metacognition influences how individuals regulate their thoughts and attention. When biased, this regulation can contribute to the development of psychological disorders (Wells & Fisher, 2016).

Beyond clinical settings, meta-cognition can improve decision-making and learning processes in everyday life as well by supporting better awareness and control over one’s cognitive processes. Previous theories such as Sternberg's (2003) Balance Theory of Wisdom highlights self awareness to improve judgment accuracy. Consistent with this view, empirical studies on meta-cognition have shown that individuals with high meta-cognitive awareness tend to make more accurate judgments and decisions, because self-reflection supports the detection and correction of cognitive biases (e.g.

Schwartz & Metcalfe, 1994; Brinol & DeMarree, 2012; Brycz et al., 2019). Moreover, meta-cognition improves divergent and convergent thinking, which is important for creative thinking and it enables us to generate ideas, recognize patterns, analyze information, and evaluate alternatives (Jiang et al., 2023). In fact, these findings show that meta-cognitive awareness improves our cognition in many different ways.

As highlighted above, research on meta-cognition is broad, spans many disciplines and offers important insights into how people think or make decisions. Consequently, the role that meta-cognition can play in learning, decision-making, or self-regulation varies depending on the field of study. In the context of political extreme's cognition, meta-cognitive awareness could help people to recognize the limits of their knowledge and adjust their beliefs accordingly. Alternatively, low meta-cognitive awareness could lead to greater cognitive rigidity, especially when individuals hold strong political beliefs with high confidence and are less willing to consider alternative views. Research on political extremism supports this idea. Political Extremists are often characterized as overconfident and resistant to self-reflection (Tetlock, 1986), suggesting cognitive rigidity and impairments in meta-cognitive awareness. Studies show that higher levels of political extremism are associated with higher intolerance toward opposing views and are often driven by strong moral convictions that predict intolerance (Skitka, 2010) and overconfidence (Van Prooijen & Krouwel, 2019). Moreover, individuals that hold polarized beliefs often show lower levels of cognitive flexibility and difficulties in shifting their perspective (Zmigrod & Goldenberg, 2021). These characteristics are typical for individuals who are less likely to engage in self-reflection or to change their beliefs when confronted with contradicting information.

Consistent with this literature, other research demonstrated that higher meta-cognitive awareness can mitigate political extremism by fostering open-mindedness and cognitive flexibility. Previous research has highlighted the importance of metacognition in learning (Paris & Winograd, 1990) and belief-updating (Geers et al., 2024). Geers et al. (2024), for example, showed that people with greater metacognitive awareness were less susceptible to climate change misinformation. When individuals fail to recognize their own misconceptions, they are less likely to look for additional information, which can reinforce misinformation and deepen ideological division. Therefore, high metacognition is important for correcting false beliefs and to maintain a shared factual basis, both of which are essential for democracy (Geers et al., 2024). Therefore, raising meta-cognitive awareness may contribute to reducing political extremism by promoting more flexible and balanced cognitive processing.

However, some studies suggest that increasing meta-cognitive awareness alone could not lead to more moderate political views. O'Leary and Fletcher (2024) found that reflecting on counter evidence can promote belief updating, regardless of whether that reflection is metacognitive or not. Additionally, they reported no significant relationship between belief updating and political extremity which contradicts earlier research linking political beliefs to metacognitive sensitivity, and belief updating (Rollwage et al., 2018). By contrast, Fernbach et al. (2013) discovered that when people with polarized views were asked to explain policies more detailedly, their perceived comprehension of those concepts decreased and led to more moderate positions. In fact, these findings suggest that extreme beliefs often arise from unjustified confidence, which can be modified when gaps in knowledge are made more noticeable.

Taken together, these findings highlight the complexity of metacognition and its role in extreme political belief formation. Meta-cognitive processes may entail accurate self-monitoring but also miscalibration or overconfidence, which can reinforce rather than reduce extremism. Indeed, O'Leary and Fletcher (2024) acknowledged that their findings may contrast previous studies because their participants may have engaged in unintended forms of metacognitive reflection, complicating the implications of their results (e.g. certain questions might have prompted them to consider counterevidence more deeply than expected).

Metacognition has many diverse mechanisms and overlaps with related processes such as reflection. In order to better comprehend metacognition's moderating effect in political extremism, it should be investigated alongside other contributing factors, including cognitive rigidity and neural markers. While its effects on learning are widely known, its influence on extremism is poorly understood. A thorough analysis that considers the interaction between cognitive and neural mechanisms is therefore important to understand how metacognition shapes extreme political views.

1.3.3 Cognitive rigidity and extremism

Individual differences in vulnerability to extreme political behavior have been linked to underlying cognitive traits including multiple psychological areas. One core information-processing style associated with ideological thinking is cognitive rigidity (Zmigrod, 2020). Cognitive rigidity describes the difficulty to adapt behavior to changing environments, task demands, and reward contingencies (Zmigrod & Goldenberg, 2021). People with lower cognitive flexibility often struggle with tasks like the Wisconsin Card Sorting Test (WCST) and the Alternative Uses Test, both of which require adaptability in processing visual or linguistic information. In the WCST, for example, participants have to categorize cards based on attributes like shape or color. When the sorting rule changes, those with greater cognitive flexibility adjust their responses accordingly, whereas individuals with cognitive rigidity have difficulty adapting to the new requirements (Zmigrod & Goldenberg, 2021).

Cognitive rigidity literature has its origins in early work on dogmatism and rigid thinking (Rokeach, 1960). Additionally, early political psychologists found that prejudices and ideological thinking are linked to mental rigidity that goes beyond political cognitive tasks and to basic cognitive processes, including perceptual processing (Adorno et al., 1950). Following this, the rigidity-of-the-extreme hypothesis was formed, stating that rigidity is associated with ideological extremism regardless of political orientation.

Advancements in cognitive psychology and neuroscience allow for more precise testing of cognitive rigidity using advanced technology and neuropsychological measures. These methods have demonstrated that individuals differ in their level of cognitive rigidity by assessing behavioral flexibility and rule adherence (Ionescu, 2012). In fact, these cognitive methodologies offer a more objective approach of measurement, while self-report questionnaires and social psychology tools are often subject to social desirability biases. Applying such tools to political cognition and extremism, recent research has found that individuals with higher cognitive rigidity in neuropsychological tasks, such as the WCST, are also more likely to endorse ideological and dogmatic beliefs (Zmigrod, 2020). This relationship extends to nationalism (Zmigrod, Rentfrow, & Robbins, 2020), political ideology (Van Hiel et al., 2016; Zmigrod, 2020) and is observed in individuals at both extremes of the political spectrum (Zmigrod, 2020). Additional research supports that cognitive inflexibility is linked to extremist attitudes and an increased willingness to engage in political violence (Zmigrod et al., 2019). In fact, cognitive rigidity has also been related to nationalism (Zmigrod et al., 2018), religiosity (Zmigrod et al., 2018), and dogmatism (Zmigrod et al., 2019; Van Prooijen & Krouwel, 2016), but the present study specifically focuses on extremist attitudes. One source of empirical support for understanding political extremism through cognitive and emotional measures comes from Rollwage et al. (2018), who recorded perceptual decision-making and confidence judgments in individuals with radical beliefs. Participants completed a low-level perceptual decision-making task, in which they had to judge the direction of moving dots and subsequently rate their confidence. The researchers made several important discoveries: First, individuals with more radical beliefs and higher intolerance showed lower metacognitive sensitivity, meaning they had reduced insight into the accuracy of their decisions. Second, these individuals were more confident in incorrect decisions. Moreover, the study found that dogmatic intolerance was associated with reduced integration of disconfirming evidence. This suggests that cognitive inflexibility may contribute to resistance to new information, reinforcing radical beliefs.

While the studies above have found robust behavioral links between cognitive rigidity and ideological extremism, little is known about the underlying neural mechanisms. Zmigrod & Goldenberg (2021) also highlight the need for cognitive neuroscience approaches to better understand the complex origins of extreme ideological behavior. The present study addresses this gap by investigating both cognitive and neural markers that are associated with political extremism. To achieve this, our study measures cognitive rigidity and meta-cognitive awareness using a perceptual decision-making task and neuroimaging. This method builds on prior studies demonstrating that inflexible belief updating and reduced meta-cognitive sensitivity can be detected in low-level perceptual decision-making tasks (Rollwage et al., 2018). They found that radical participants displayed less insight into the correctness of their choice, fewer changes of mind and reduced updating of their confidence even when presented with countering evidence. Studying cognition through a perceptual decision making task, especially meta-cognition or cognitive rigidity, offers several advantages: it minimizes the effects of previous knowledge, ideological content or motivational factors. Adding neural imaging, as implemented in the current study and discussed in more detail in a later section, allows us to bridge the gap in understanding the underlying neural mechanisms. In fact, decision-making neuroscience offers a more neutral framework for studying political extremism and the underlying cognitive and neural mechanisms from a generic, content-independent perspective.

1.3.4 Feedback Manipulation

Recent studies support the neurocognitive model of ideological thinking and emphasize the connection between perceptual decision-making processes and higher-level ideological beliefs (Zmigrod, 2021). In fact, increasing attention has been given towards understanding how cognitive processes influence the formation and maintenance of ideological beliefs (Zmigrod, 2021). Building on this research, the current study aims to enhance the understanding of the neurocognitive underpinnings of political extremism by manipulating feedback during a perceptual decision-making task. Specifically, we will compare a no-feedback versus feedback condition in a dot-motion task to examine whether exposure to performance feedback influences decision-making in Extremists versus Moderates differently. By assessing behavioral factors (e.g. willingness to adapt, non-decision time) and neural markers (e.g. evidence accumulation, event-related potentials) the study will explore how decision-processes relate to ideological rigidity. These measures will also be discussed in more detail in the following EEG section.

Prior research that manipulated feedback has highlighted its importance for metacognitive processing, defined as the ability to monitor one’s own cognitive performance. Metacognition is highly sensitive to feedback in daily life. However, its role in perceptual decision-making remains unclear. Luo and Liu (2023) investigated how trial-by-trial feedback shapes perceptual metacognition across different task difficulties. They found that in high-difficulty tasks, feedback led to minor improvements in metacognitive efficiency when performance was controlled, whereas feedback improved metacognitive efficiency in low-difficulty tasks. These findings suggest that feedback effects on metacognition depend on task difficulty. This has implications for the present study: it raises the possibility that Extremists could show reduced metacognitive adaptation to feedback especially under high task difficulty. In fact, a resistance towards feedback-driven adjustments would be consistent with cognitive rigidity and could give new insights into decision-mechanisms that sustain political extremism.

Direct research on the effects of feedback versus non-feedback conditions in political Extremists is limited. Instead, studies have explored feedback in broader social and communication contexts. For example, negative feedback can moderate extreme rhetoric and reduce echo chambers, as individuals adjust their tone in response to corrective feedback (Deolankar et al., 2024). Other research found that the exposure to opposing views can increase polarization and reinforce existing beliefs (Bail et al., 2018). Together these studies highlight the complex dynamics of feedback more generally and effects of counter-attitudinal information on political attitudes.

Although these studies do not test feedback effects in low-level perceptual decision-making tasks, other work has looked more into the metacognitive characteristics of radical beliefs using such tasks. Rollwage et al. (2018) examined how individuals with radical beliefs integrate post-decision evidence in a perceptual decision-making task. Participants made decisions about a flickering dot-motion stimulus and were later presented with additional evidence before rating their confidence. Compared to Moderates, more radical individuals exhibited reduced insight into their decision accuracy. Additionally, radicals showed a reduced integration of disconfirmatory evidence, meaning they were less likely to lower their confidence when new evidence indicated their initial choice was incorrect. Computational modeling suggested that this reduced updating reflected a choice bias, where radicals assigned undue probability to their initial decision rather than integrating new information (Rollwage et al., 2018). These findings provide an idea of how feedback and post-decision information are processed differently by people with radical beliefs and they motivate the present study’s focus on feedback-driven updating in perceptual decision-making.

Specifically, the current study introduces an explicit trial-by-trial feedback (correct/incorrect) versus a non-feedback condition in a standard dot-motion task. This distinction is important, because external feedback could engage different cognitive and neural mechanisms than self-driven post-decision evidence integration, that is used by Rollwage et al. (2018). Whereas their work focused on implicit confidence updating, the current study explicitly tests whether corrective feedback can alter decision-making in more extreme versus more moderate participants. Additionally, this study incorporates EEG to measure event-related potentials (ERPs) to investigate error sensitivity and cognitive updating. This will allow assessment of whether Extremists show weakened neural responses to feedback, and it will provide insights into the neurocognitive mechanisms that underlie their resistance to correction. By analyzing evidence accumulation, and behavioral adaptation over time (e.g. reaction times), this study will extend previous findings and examine whether feedback leads to behavioral adjustments across feedback trials and blocks. In fact, we will also implement no feedback blocks, in which participants will not receive any feedback regarding their performance, to see whether there are differences in neural and behavioral responsiveness throughout these two alternating conditions. Specifically, we will investigate error awareness and adaptive evidence accumulation across the feedback versus no feedback blocks, with the associated neural processes described in more detail in the following sections.

Research in decision neuroscience has shown that feedback plays an important role in perceptual learning (Liu, Dosher & Lu,, 2014): Feedback on performance accuracy can influence whether learning occurs and it can inform more effective training strategies. Whether these learning mechanisms apply to Extremists as well will be addressed by the present study. Perceptual learning research differentiates between two main types of feedback: trial-by-trial feedback, where participants receive correct/incorrect signals after each trial, and block feedback, in which only a summary on accuracy is given after a full block of trials (Liu, Dosher & Lu,, 2014). Although learning can be achieved even without external feedback (e.g., Petrov et al., 2006; Crist et al., 1997), trial-by-trial feedback is generally associated with stronger performance improvement and is the standard in perceptual learning experiments. The idea that feedback enhances performance has been supported for over a century (Judd, 1905). However, recent studies suggest that feedback does not improve performance through simple reinforcement alone. Instead, its effectiveness depends on whether individuals adjust their decision strategies (Haddara & Rahnev, 2022). Haddara and Rahnev (2022) found that with trial-by-trial feedback participants adjusted their response strategies: they showed reduced response bias and metacognitive distortions, even without direct reinforcement effects on perceptual and metacognitive sensitivity. This shows that feedback can lead to more strategic adjustment rather than pure perceptual learning.

Building on these findings, the present study explores how explicit trial-by-trial feedback impacts decision-making in Extremists. We will, therefore, test whether feedback reduces response bias and improves confidence calibration across groups, or whether Extremists show weaker adaption to feedback. Additionally, we will look at whether feedback affects perceptual or metacognitive sensitivity differently across Moderates and Extremists.

Previous research has criticized purely behavioral measures and argued that confidence ratings alone are not enough for assessing metacognition. Liu et al. (2024) argue that simply asking individuals how confident they are in their decisions does not capture the quality of their decision-making. Instead, they find that brain regions such as the anterior insula and dorsomedial prefrontal cortex (dmPFC) track how well individuals evaluate their choices beyond simple behavioral confidence ratings (Liu et al., 2024). This underscores the importance of using both behavioral and neural measures of decision making. Therefore, the current study combines accuracy, confidence, and neural measurements to assess feedback-driven decisions and metacognitive processes more comprehensively.

Research in decision neuroscience has shown that metacognitive sensitivity relies on mechanisms that support monitoring and updating confidence in prior decisions (Van den Berg et al., 2016; Fleming et al., 2018). This ability depends on the prefrontal cortex (Fleming et al., 2017) which is involved in performance monitoring and self-evaluation. And even in the absence of explicit feedback, it enables individuals to recognize errors internally (Rabbit et al., 1966; Yeung & Summerfield, 2012). Although most research on extremism has focused on motivational and emotional factors, growing research links metacognitive capacity and related cognitive mechanisms to radical belief systems and their resistance to change (Rollwage et al., 2018; Zmigrod et al., 2021). Notably, Rollwage et al. (2018) demonstrated that simple perceptual discrimination tasks provide an objective measure of Extremists' metacognitive abilities.

Ultimately, this study aims to understand how explicit feedback influences Extremists' decision-making and meta-cognitive processes. By comparing both feedback and non-feedback conditions, the study looks at how cognitive and neural processes interact to support or constrain adaptive belief updating in political extremism.

Overall, a limited amount of work has examined the decision process itself and whether Extremists apply different decision-making strategies. For example, participants may vary in the amount of evidence they require in order to commit to a choice, which is referred to as the "decision threshold" in computational models. Moreover, participants can vary in how accurately they encode evidence and in the weighting with which accumulated evidence is translated into subjective confidence. Whether decision-making thresholds, neural signals and meta-cognitive awareness moderate political extremism remains an open question. The present study addresses this gap by investigating neural and cognitive differences between moderate and extreme individuals using EEG during a perceptual decision-making task. By integrating decision neuroscience with established psychological theories of extremism, this study aims to provide a more comprehensive understanding of the cognitive and neural mechanisms that underlie ideological rigidity and belief persistence.

1.4 Empirical findings across cognitive, behavioral, and neurophysiological levels of political extremism

1.4.1 Neurophysiological Investigations

Non-invasive approaches such as electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) allow for a global view of brain function associated with ideological beliefs. For example, Pedersen et al. (2018) found that economic conservatism is linked to increased amygdala-BNST connectivity during periods of threat versus safety, which suggests a heightened neural response to perceived danger. Similarly, Kanai et al. (2011) found structural differences linked to political orientations, with conservatism associated with increased gray matter volume in the right amygdala and liberalism with increased anterior cingulate cortex volume. These findings suggest not only that political attitudes are reflected in human brain structure but also that there may be a link between brain structure and psychological mechanisms that mediate political attitudes. In fact, such studies contribute to understanding ideological extremism at the neural level and provide additional insights into how neurophysiological and psychological evidence shape political beliefs.

A few non-invasive studies on political extremism have also been conducted using electroencephalography (EEG). For example, Howard (2025) examined the neurocognitive processes involved in radicalization, by focusing on how message content and production features can evoke empathy and lead to radical persuasion. The study used EEG to identify empathic and related neural responses to radical messages and propaganda. Their findings suggest that inducing empathy can enhance radical-persuasive effects and increase the potential for violent radical political behavior.

Political extremism has also been studied using self-reported measures and surveys. For example, Iqbal et al. (2022) demonstrated that indicators of existential anxiety correlate with increased support for violent extremism through an anonymous online-survey. Cognitive rigidity has also been examined using problem-solving tasks to assess its relationship with common features in political extremism, such as socio-cognitive polarization, receptivity to “bullshit”, and overclaiming (Salvi et al., 2023). Salvi et al. (2023) found that participants that were low in these traits (i.e., less rigid), performed best in problem-solving tasks. The study concludes that higher social rigidity predicts cognitive rigidity, reinforcing the link between dogmatic belief systems and lower adaptability in reasoning.

Nevertheless, cognitive and neurophysiological research provide more objective and quantifiable measures of political extremism. This is rarely the case in direct assessments of political attitudes or self-reported measures, where the ground truth is often unknown and limited by subjectivity.

Decision neuroscience paradigms, such as dot-motion or Gabor patch tasks, allow precise assessments of cognitive flexibility and metacognitive sensitivity. Importantly, these paradigms enable us to assess decision-making processes in tasks that are devoid of political or ideological content, therefore allowing the testing of fundamental cognitive differences that are not confounded by cultural, societal, or motivational influences. In addition, EEG studies have highlighted the value of neural signals to capture the temporal dynamics of belief formation and decision-making (Howard, 2025; Mulder, 2014). To date, however, there has been a lack of studies combining EEG with perceptual discrimination tasks to investigate political extremism. Although it did not investigate political extremism, a study by Rollwage et al. (2020), combined human magnetoencephalography (MEG) with behavioral and neural modelling to identify how individuals evaluate evidence encountered after a decision has been made in order to understand the origins of confirmation bias. The study finds that high decision confidence impacts post-decision neural processing because it over-weights confirmatory evidence and suppresses disconfirmatory evidence. This suggests that confidence selectively filters information in favor of one's initial choice, which makes changes of mind less likely (Rollwage et al., 2020). Confirmation bias has been found in people with polarized beliefs (Lord, Ross & Lepper, 1979; Rollwage et al., 2020) and this study, therefore, is relevant in the context of political extremism as well. However, it also highlights the necessity of studies that combine neural and behavioral modeling.

The goal of our EEG study, therefore, is to more thoroughly investigate neural oscillations, as well as error-related and decision-making-related brain activity, in individuals with extreme ideological positions. By integrating decision neuroscience with behavioral discrimination tasks, this study aims to advance understanding of how cognitive and neural underpinnings contribute to extremism. Previous research that integrated decision neuroscience with behavioral discrimination tasks (e.g., Gabor patches) has provided insights into the cognitive mechanisms underlying resistance to evidence-based belief updating, extreme moral choices, reduced awareness of decision accuracy and overconfidence (Rollwage et al., 2020; Osorio & Reyes, 2025). These interdisciplinary approaches offer a comprehensive framework for examining political extremism through cognition, affect and neurophysiological processes in future research, especially when combined with neuroimaging techniques.

1.5 Neural Markers and Political Decision-making

1.5.1 Centro-parietal Positivity (CPP)

The centro-parietal positivity (CPP) is an event-related potential (ERP) that reflects the brain's accumulation of sensory evidence during decision-making tasks. It tracks the gradual buildup of information over time until a decision threshold is reached and the choice is reported(O'Connell et al., 2012). The CPP increases in amplitude when sensory evidence becomes stronger, and its rate of build up predicts both the speed and accuracy of decisions (Kelly & O'Connell, 2013). Kelly and O'Connell (2013) further studied the relationship between CPP and decision-making speed by investigating how internal factors influence evidence accumulation. They found that greater attentional focus corresponds to faster CPP accumulation and lower alpha-band (α-band) activity. Alpha-band activity reflects attentional disengagement (Kelly & O'Connell, 2013) which results in slower evidence accumulation and slower reaction times. However, α-band activity alone does not directly predict decision speed, because the rate of CPP buildup is a more reliable indicator of decision-making dynamics.

In tasks that include sensory evidence, such as shown in O'Connell et al.'s (2012) gradual-change detection task, participants monitored visual patterns for changes in contrast. In this task, the steady-state visual evoked potential (SSVEP) enabled them to measure sensory evidence, which reflected the amplitude of the visual contrast that participants used to make decisions. Importantly, differences in SSVEP amplitude were observed in relation to RT, which enabled them to identify the SSVEP as a reliable sensory evidence signal (O'Connell et al., 2012). As the CPP built up during decision formation, it also showed a quadratic relationship with the sensory evidence, reaching a threshold that triggered action (O'Connell et al., 2012). This build-to-threshold mechanism was observed across tasks, which included the motion discrimination tasks, where the CPP buildup rate increased as the strength of sensory evidence (e.g., the coherence of moving dots) increased (O'Connell et al., 2012).

These studies highlight the important role of CPP as a decision variable signal: it reflects the accumulation of sensory evidence in addition to internal cognitive processes, such as attentional engagement and motor preparation. The CPP is important to understand how the brain weighs evidence and makes decisions, especially in dynamic environments where sensory input is always updated, and where decisions need to be made fast and accurately (Kelly & O'Connell, 2013; O'Connell et al., 2012).

In addition to reflecting the accumulation of sensory evidence, the CPP operates across multiple sensory modalities, specifically different sensory modalities and motor tasks. This means the CPP shows a similar evidence-dependent buildup regardless of the motor requirements (button press versus counting), sensory modality (e.g., audition or vision), or the target-defining feature (e.g., upward or downward intensity changes, pitch changes, or dot-motion discrimination) (O’Connell et al., 2012; Kelly & O'Connell, 2013). This “supramodal” characteristic makes the CPP a domain-general decision variable and suggests that it accumulates evidence in a flexible way, which is not just tied to specific sensory features or motor responses.

An important feature of these neural decision signals is that they exhibit choice-relevant dynamics that are highly consistent with the predictions of a long-standing class of mathematical models, known as Sequential Sampling models. Sequential Sampling models hold that evidence is repeatedly sampled and accumulated over time until a preset quantity has accrued (referred to as the ‘decision boundary’), triggering commitment to a choice (Forstmann et al., 2016). This model is widely applied in decision-making tasks and used to explain many different cognitive phenomena, including speed-accuracy tradeoffs and choice biases due to prior knowledge. These models thus provide a powerful theoretical framework that has guided the interpretation of neural signatures of decision formation like the CPP.

Applying these frameworks to a split group of political Moderates and Extremists is groundbreaking because it links cognitive rigidity with neural evidence accumulation. This approach offers a more objective measurement of differences in decision-making between two very distinct groups. This connection is relevant to my research project, which investigates neurophysiology and cognition across moderate and extreme political worldviews. For example, individuals with higher levels of cognitive rigidity, as often seen in Extremists (Zmigrod et al., 2021), may show differences in CPP buildup rates, potentially reflecting slower or more rigid decision-making processes. By leveraging the CPP and neural evidence accumulation models, this current study can explore how moderate and extreme individuals differ in the rate and efficiency of accumulating evidence. This offers new insights into the neurophysiological mechanisms that underlie ideological extremism.

Additionally, the CPP provides valuable insight into post-choice confidence (O'Connell & Kelly, 2021). Grogan et al. (2023) showed that confidence is predicted by pre- and post-choice CPP dynamics: pre-choice CPP scales with subjective confidence and post-choice CPP persists especially when certainty is low. Their findings support certainty-dependent stopping theories, according to which evidence accumulation continues until a confidence threshold is met. This aligns with Bayesian models of metacognition, which view self-evaluation functions (e.g. confidence) as a second-order inference process that works distinct from the first-order decision system (Fleming & Daw, 2017).

Previous research only investigated confirmation bias using approaches that are similar to this present study. Rollwage et al. (2020) found that confirmation bias is reflected even in low-level perceptual decision-making tasks and neural evidence accumulation. Using MEG, they measured neural indices of evidence accumulation and found that after highly confident decisions, the brain selectively accumulated evidence that would only confirm the initial choice while largely ignoring disconfirmatory information. This highlights how confidence can bias post-decisional processing: it makes the evidence accumulation process "blind" to information that challenges prior beliefs. To better understand biases in higher-order cognition, Rollwage et al. (2020) argue that models of evidence accumulation should include post-decisional processing. They have shown with their findings that even simple perceptual decision-making tasks can reveal mechanisms relevant to belief formation, polarization, and extremism. Post-decisional processes and the continued integration of evidence after a choice has been made, have also been linked to broader political and ideological attitudes. Therefore, investigating the centro-parietal positivity (CPP) in such contexts could provide valuable insights into how individuals with extreme political views process information and monitor their decisions. Additionally, it enables the investigation of cognitive inflexibility and confirmation bias at a neural level. Specifically, the feedback condition employed in this current study will allow the investigation of whether Extremists show diminished neural responses to feedback over time and it offers insights into neural underlyings of resistance and correction. Therefore, we will move beyond self-reported confidence to examine the neural mechanisms underlying feedback-based learning, error sensitivity and cognitive updating. Ultimately, these insights could inform interventions to enhance metacognitive awareness and reduce polarization.

In conclusion, our study will use a novel way to measure how the brain processes information and integrates evidence. By combining behavioral and neural measures, this research project may provide deeper insights into the cognitive and neural mechanisms that are linked to extreme political views and offer contributions to both political psychology and decision neuroscience.

1.5.2 EEG and the political mind

EEG has rarely been used to investigate radicalization and harmful intentions, resulting in very limited literature on neural signals that underpin such cognitive processes. One of the few existing studies in this area is a study by Kim et al. (2020) who combined EEG-based trustworthiness measures alongside self-reports to examine cognitive responses to insider threat scenarios. Their classification model was able to detect malicious intentions with 78.57% accuracy and differentiated insider threat situations from everyday conflict scenarios with an accuracy of 93.47% (Kim et al., 2020). This demonstrates that EEG can objectively identify neural signatures associated with harmful intentions and moral decision-making. Similarly, regarding radicalization, Howard (2025) used EEG to track empathic responses to extremist propaganda videos. They monitored arousal levels through the beta/alpha ratio and delta wave activity in the prefrontal cortex as indicators of cognitive empathy processing. The study showed that empathy is activated in individuals during their radicalization process, primarily in response to themes of pain, victimization, strength, and patriotism.

Decision neuroscience also has the potential to improve our understanding of political extremist behavior, though it has yet to be applied using EEG. Previous studies, such as Galli et al. (2017), have used EEG to examine political extremism through event-related potentials (ERPs) and multivariate pattern analysis, suggesting that neural activity could predict aggregate voting choice in future studies. Other research has explored ERPs and found that greater liberalism was associated with stronger conflict-related anterior cingulate activity, indicating a higher neurocognitive sensitivity to cues for changing habitual response patterns (Amodio et al., 2007). In line with this, Galli et al. (2017) showed that the N400 response to statements incongruent with one's views on the EU, predicted actual voting behavior, even better than self-reported preferences. This highlights that EEG markers can capture implicit ideological processing and that neural measures can provide unique insights into political attitudes beyond self-report.

Despite these advances, neurophysiological mechanisms of extremism remain underexplored, as most research focuses on psychological motivations. Cognitive research has mostly focused on behavioral measures, such as the Wisconsin Sorting Task or dot motion tasks, linking dogmatism to reduced speed of perceptual evidence accumulation (Zmigrod et al., 2021; Rollwage et al., 2020). The present study builds on these findings by integrating EEG to examine the neural underpinnings of perceptual decision-making. Specifically, EEG allows the investigation of pre-decision Centro-parietal Positivity (CPP) amplitudes, which can test whether slower accumulation in extreme individuals is reflected at the neural level as well. Moreover, EEG measures such as the error-related negativity (ERN) response, as well as the Error Positivity (Pe), can be used in future to explore feedback sensitivity in Extremists versus Moderates, while the P3 amplitude can provide insights into attentional engagement and cognitive updating. Lastly, post-decision CPP changes may reveal whether Extremists show resistance to feedback-based adjustments or a weakened decision reevaluation. Importantly, EEG provides the opportunity to move beyond behavioral measures, allowing the capture of task-related neurophysiological markers of cognitive effort and executive control. As Balconi et al. (2023) suggest, metacognitive skills play a critical role in regulating performance efficacy and efficiency, and neurofunctional markers enable deeper insights into these mechanisms, especially into how cognitive resources are allocated and adjusted during complex decision-making tasks. This perspective highlights the potential of EEG to understand how metacognitive awareness and perceptual decision making interacts with neural markers of cognitive effort, feedback sensitivity, and decision confidence across politically more moderate and more extreme participants. By examining differences in pre- and post-decision EEG components, such as CPP amplitudes, this study aims to uncover whether more extreme participants show different neurophysiological patterns that may underlie cognitive rigidity and resistance to corrective feedback.

EEG has been widely used in decision neuroscience to understand the neural mechanisms that underlie high-level cognition. Grogan et al. (2023) showed that confidence is predicted by pre- and post-choice CPP dynamics. In this framework, individuals assess their own performance similarly to how they would judge another person's accuracy, which allows dissociation between task performance and metacognitive insight. Longer CPP activation in uncertain choices could reflect the ongoing second-order computation, where confidence judgments continue to be refined after a decision has been made, especially when external feedback is absent. These findings suggest that neural mechanisms that underlie decision confidence can provide insight into broader metacognitive processes, including error detection and self-evaluation across various domains.

Individual differences in these mechanisms could help to explain why some people are better at recognizing when they are wrong, while others struggle with self-evaluation. This can also have important implications for decision-making, learning, and behavioral change, especially in situations where external feedback is absent - such as political and ideological beliefs. Despite this relevance, to our knowledge, EEG has rarely been applied to Extremists, even though ideological worldviews have been linked to low-level perceptual and cognitive function (Zmigrod et al., 2021). Aside from the Rollwage et al. (2020) MEG study mentioned above, extremism has rarely been the subject of any neuroimaging investigation. Building on this methodological approach, our current study expands prior findings by investigating how corrective feedback influences decision-making in individuals with extreme versus moderate beliefs. Instead of MEG, this study uses EEG to measure ERPs and to investigate error sensitivity and cognitive updating, ultimately shedding further light on the neural origins of extremism. By tracking behavioral and neural changes across trials, this project aims to determine whether feedback can promote adaptive updating and potentially counteract confirmation bias. Therefore, it may provide a different account of how feedback could reduce polarization in individuals with extreme views.

Despite the promising progress on neural markers of extremism related traits, most neuroscientific studies on political ideology rely on fMRI rather than EEG (e.g., Schreiber et al., 2013; Ahn et al., 2014). There is a notable lack of studies that have examined the neural signals of perceptual decision-making in political Extremists. This gap is surprising given that ideological beliefs are linked to basic cognitive and neural processes and given that extremism may be reflected in low-level decision mechanisms rather than only high-level motivational factors. As discussed above, applying EEG-based decision neuroscience to more extreme populations can be valuable to identify the neural and computational mechanisms that impact ideological rigidity and the resistance to change.

Indeed, the neurophysiological models discussed in the previous sections could be applied to a moderate versus more extreme sample in several ways: CPP, which describes cumulative evidence accumulation, could provide more insight into how these two groups process and accumulate information during decision-making tasks differently. Similarly, mu/beta activity, linked to motor preparation and execution, may indicate differences in decision preparation between the two groups. DDM parameters like drift rate and bound could differentiate Moderates from Extremists based on how quickly they accumulate evidence and how much certainty they require before making a decision. In fact, EEG allows the analysis of a range of neurophysiological signals that may contribute to the cognitive and neural differences observed in more extreme participants in previous research. This study will primarily focus on investigating the CPP locked to different events such as error-related or feedback-locked trials. This can enhance our understanding of error and feedback awareness, or the lack thereof, in more extreme versus more moderate participants. Future research may also look more into signatures of ERN and Pe.

Being able to recognize one's own errors and adjusting behavior is essential for daily life. In political Extremists, a lack of self-reflection or conscious awareness of one's own errors might explain why someone holds onto strong beliefs, no matter how wrong they seem. Researchers have investigated the neural correlates of error processing and subsequent behavioral adjustment more thoroughly (Kirschner et al., 2021). Previous studies found that the Pe can predict participants' error awareness and is linked to conscious error perception (O'Connell et al., 2007). The research on error positivity (Pe) seems clearer than the previously discussed ERN signal, as Pe is only present when participants are aware of their errors (O'Connell et al., 2007). Murphy et al. (2012) demonstrated that both the amplitude and onset of the Pe correlate with the timing of error awareness, meaning the individual has perceived their own mistake. Beyond being a neural marker of error detection, a recent study by Kirschner et al. (2021) examined behavioral adjustments following consciously perceived and unperceived errors. They found that error awareness plays a mediating role in behavioral adjustments, suggesting it is essential for meta-control processes such as meta-cognitive awareness (Kirschner et al., 2021). However, latest research suggests that the Pe signal can be understood as a continuation of the same process indexed by the CPP. In fact, the Pe signal may simply reflect an evidence accumulation process that occurs after erroneous choices (Grogan et al., 2023). This evolving understanding of the Pe signal, as a post-error evidence accumulation process, opens new ways for studying how individuals process and become aware of their mistakes. Specifically, examining both the Pe and the ERN can provide valuable insights into individual differences in error monitoring and cognitive control. Focusing on the CPP, locked to error versus no error trials, may give equally insights into post-error evidence accumulation. This current study will therefore focus on post-error locked evidence accumulation signatures.

Investigating post error CPP, as well as Pe and ERN, may help us analyze differences in error detection between more moderate versus more extreme participants. These neurophysiological measures may answer more questions about cognitive differences, previously observed in the extreme mind (Zmigrod et al., 2020). For example, do Moderates show stronger post-error neural signals because they are more aware of themselves and their errors? Conversely, do more extreme participants display more pronounced ERN deflections or none at all?

By applying EEG to study political extremism, this study will measure neural correlates of decision certainty, cognitive inflexibility, and metacognitive deficits, which have been explored mainly through behavioral measures so far (Rollwage et al., 2018; Zmigrod et al., 2020). This methodological approach provides objective and neurophysiological evidence for how moderate and extreme individuals differ in perceptual decision-making. The study examines differences in evidence accumulation, error detection rates, decision-making thresholds and adjustments across feedback and non-feedback conditions. By combining EEG with these experimental manipulations, the study offers insights into the neural mechanisms that may drive political extremism and contributes to a more nuanced understanding of how the brain shapes decision-making in moderate versus extreme ideological positions.

1.6 The current study

This last section outlines the central research questions of this thesis, which will be addressed in detail in the following chapter. Chapter 2 provides a review of the EEG experiment, including its methods, experimental design, procedure, data analysis, results, and discussion. Finally, it provides a final conclusion.

The reviewed empirical and theoretical literature on political extremism, meta-cognitive awareness, cognitive rigidity, and the neurophysiology of decision-making suggests that there are neurocognitive differences between more extreme versus more moderate individuals. These differences potentially influence both cognition and political behavior. However, it is unknown if such cognitive and neural characteristics cause political extremism, or if politically extreme behavior reshapes cognitive processing and brain function. This classic “chicken-and-egg” dilemma highlights the need for more empirical research in cognitive neuroscience and political psychology.

The main research question of this current study is: How do individuals with more extreme versus moderate political attitudes differ in neural and behavioral markers of perceptual decision-making and metacognitive awareness?

To date, few studies have examined meta-cognition and perceptual decision-making differences across ideological groups, and investigations of neurophysiological differences associated with extremism are rare. Although low-level perceptual tasks have been shown to reveal mechanisms relevant to belief formation, polarization, and extremism (Rollwage et al., 2020), no studies, to the best of our knowledge, have directly compared neurophysiological indices of decision making across Extremists and Moderates. This research project tries to address this gap and focuses on individual-level cognitive processes rather than social group dynamics.

Understanding cognitive rigidity and meta-cognitive awareness and how they influence vulnerability to extremism is crucial to find prediction and prevention strategies. Objective cognitive and neurophysiological measures can help to address inconsistencies in previous findings and understand the role of cognition in political extremism better. In fact, this study shifts attention from predominantly social identity-based theories to individual cognitive vulnerabilities, such as impaired meta-cognitive awareness and reduced cognitive rigidity.

Chapter 2: Investigating the relationship between meta-Cognition and Political Extremism

2.1 Introduction

To study the underlying cognitive processes of decision-making in political Moderates versus Extremists, the current study uses a perceptual decision-making task. More specifically, the task is based on a psychophysical approach and assesses bias in order to measure participants' accuracy and their confidence, respectively. Moreover, the employed task allows collection of EEG data from participants and, therefore, the examination of group differences in the neural processing of decision-making, particularly in evidence accumulation and metacognitive awareness.

To date, a growing number of studies have examined overconfidence, confirmation bias, and metacognitive failure in radicals, and have found cognitive differences during perceptual decision-making tasks (Rollwage et al., 2018; Rollwage et al., 2020; Zmigrod et al., 2020). However, very few studies have examined the neural signals that underpin such differences and which could shed further light on the origins of extremism.

Several studies conducted by O'Connell and colleagues have isolated neural signatures that trace the process of decision formation (e.g., O'Connell et al., 2012; Kelly, & O'Connell, 2013). In particular, they were able to isolate the centro-parietal positivity (CPP) which represents the accumulation of evidence, during a random-dot motion task similar to the one employed in the current study. The potential individual differences in CPP signals between more moderate and more extreme decision-makers are of interest to this thesis. Moreover, recent research on overconfidence has revealed selective accumulation of neural evidence for choice-consistent information (Rollwage et al., 2020). Therefore, differences in CPP signals related to evidence accumulation should be observed when comparing moderate to more extreme individuals, as extremism has already been linked to overconfidence and differences in perceptual decision-making.

The overall objective of the current thesis is to investigate the underlying cognitive and neural processes between groups. To achieve this, it will use the random-dot motion task, which has already been validated and proven effective for investigating evidence accumulation and metacognition.

The study tests the following hypotheses:

1) Extremists will exhibit cognitive rigidity (fewer changes of mind), lower meta-cognitive awareness (lower metacognitive efficiency score as measured by AUC2), reduced confidence thresholds. This will be reflected in behavior in the form of reduced decision-confidence calibration (mismatch between actual accuracy and reported confidence), lower choice reaction times, and higher confidence ratings despite lower accuracy. This will be reflected in EEG markers in the form of smaller CPP amplitudes before decisions, and less post-decision processing (reduced post-choice CPP).

2) Moderates will exhibit higher behavioral error detection rates than Extremists, as indicated by more frequent changes of mind or corrections after mistakes, post-error slowing (i.e., increased reaction time following an error), and overall lower confidence ratings, particularly in the non-feedback condition. This behavioral measure may also be reflected in neural markers, with greater CPP amplitude following errors and indicating the conscious awareness of mistakes.

3) The provision of feedback will increase error awareness and adaptive evidence accumulation in Moderates, while Extremists will show reduced neural and behavioral responsiveness to feedback, especially to disconfirmatory feedback. Specifically, in the feedback condition, Moderates will show increased error-related processing (post-decision processing indexed by the Pe), more adaptive decision adjustments (higher confidence updating, more CoMs, increased AUC2), and enhanced evidence accumulation (greater CPP build-up). Extremists will display confirmation-biased neural processing of feedback, with blunted post-decision processing (CPP) and fewer behavioral corrections after disconfirmatory feedback.

By investigating these interactions, the study aims to understand the cognitive foundations of political extremism and contribute to the development of strategies to reduce ideological polarization.

2. 2. Methods

2.2.1. Participants

A total of 57 participants (18 years old or older, mean age = 24.88 ± 8.13 years) were recruited from the general population, university staff and students. Eight participants were excluded due to insufficient data retained after artefact rejection. The final Moderate group had n = 25 participants (15 women, 10 men; mean ES score: M = 1.66, SD = 0.26; score range: 1.07–2.00). The final Extreme group had n = 24 participants (12 women, 12 men; mean ES score: M = 3.02, SD = 0.39; score range: 2.50–3.80). A post-hoc power analysis indicated that this sample size provided sufficient statistical power (0.80) for detecting an effect size of 0.25 in a 2x2 mixed-design ANOVA (within-between interaction) at an alpha level of 0.05, and a nonsphericity correction of 1. Participants had normal or corrected-to-normal vision and were screened for any personal or family history of epilepsy, psychiatric or neurological disorders, as well as any personal history of traumatic brain injury. Participants were divided into a "more moderate" and a "more extreme" group based on their scores on the Extremism Scale (Ozer & Bertelsen, 2018). The scale is a 14-item self-report measure scored on a 7-point Likert scale (1= Strongly disagree, 7 = Strongly agree). It operationalises extremist attitudes along two dimensions: 1. Endorsement of comprehensive personal and societal change, and 2. Intolerance toward other groups. Importantly, the scale captures extremist attitudes independently of acceptance of violence or illegal means to avoid the false-positive problem of conflating non-violent extremism with violent extremism (Ozer & Bertelsen, 2018). A mean item score is computed, with higher scores indicating a greater endorsement of extremist attitudes. The Extremism Scale was validated through Exploratory and Confirmatory Factor Analysis (EFA/CFA) in a combined Danish and US sample of high-school and college students (N = 686). CFA confirmed an unidimensional factor structure with good model fit ($\chi^2(53) = 94.96$, $p < .001$; CFI = 0.97; RMSEA = 0.05; SRMR = 0.04) and item loadings ranging from 0.45 to 0.75 (Ozer & Bertelsen, 2018). Internal consistency was excellent (Cronbach's α = 0.92 across both cultural contexts). The scale also showed scalar measurement invariance across Danish and US samples, supporting its cross-cultural applicability. Construct validity was also established through theoretically consistent correlations with related measures such as the Vile World subscale (Stankov et al., 2010).

The Extremism scale was administered online as a pre-screening survey and completed on SurveyMonkey by 209 individuals; 7 responses were unusable due to incomplete data, therefore the usable pre-screening sample of N =202. The mean score in the pre-screened sample was M = 2.50 (SD = 0.73; range: 1.07–4.90). This is consistent with published norms for the scale: in the original validation study, Ozer and Bertelsen (2018) reported a mean of 2.31 (SD = 1.01) in a Danish youth sample and 2.68 (SD = 1.22) in a matched US youth sample. The somewhat smaller standard deviation in the current sample likely reflects the general adult population context (mean age = 24.88). Figure 1 shows the distribution of ES scores across the full pre-screened sample. Scores were approximately normally distributed and right-skewed, consistent with low base rates of strongly held extremist attitudes in a general population sample. The majority of scores fell between 1.50 and 3.00, with 27% of the sample scoring in the moderate range (≤2.0) and 48% scoring in the extreme range (≥2.5).

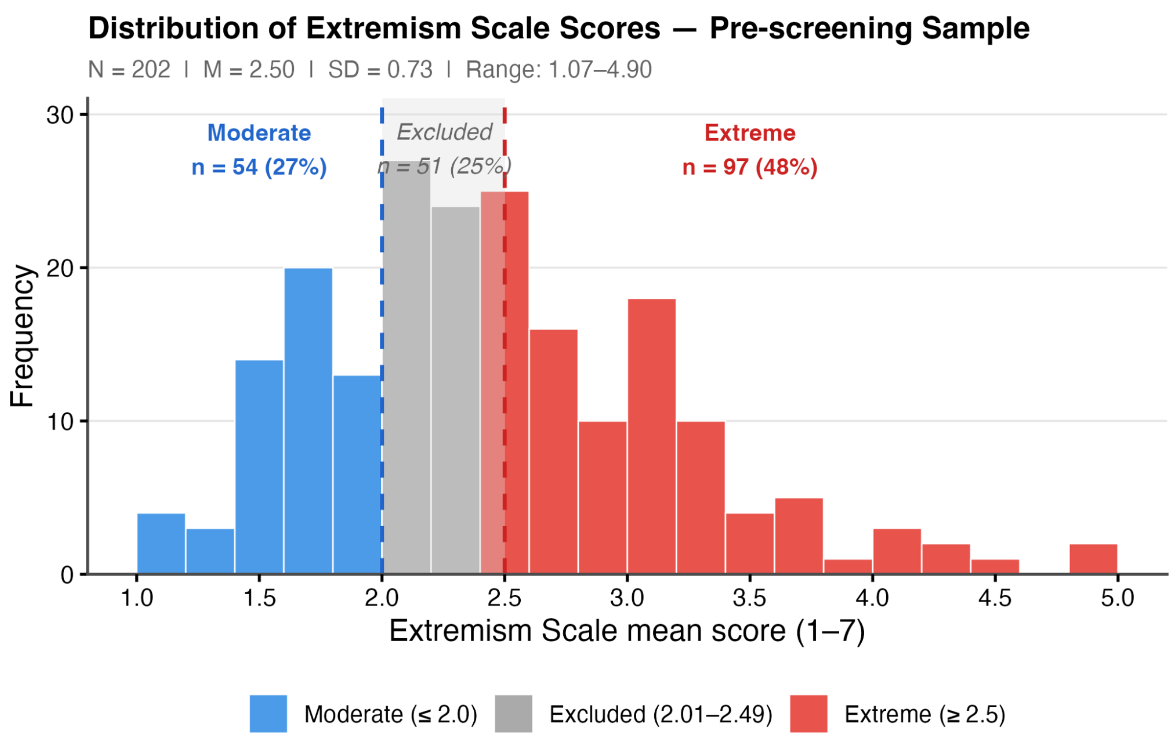


Figure 2.2.1: Histogram of pre-screening Extremism Scale scores (N = 202). The x-axis shows mean ES score (1–5); the y-axis shows frequency. Dashed vertical lines indicate the cut-off

thresholds at 2.0 (Moderate boundary) and 2.5 (Extreme boundary). The shaded band (2.01–2.49) represents the middle zone excluded from group assignment.

Based on their mean Extremism Scale scores, participants scoring ≤ 2.0 were classified as "more moderate," whereas participants scoring ≥ 2.5 were classified as "more extreme." Individuals who scored between 2.01 and 2.49 (n = 51; 25% of the pre-screened sample) were not invited to participate in the in-person study. This 0.5-point exclusion gap was adopted to ensure that the two groups reflected meaningfully distinct profiles rather than a simple median split, which would risk including borderline individuals who may not reliably differ in their ideological orientation.

All participants were required to give written informed consent prior to any data collection and were paid 20€ for their time (10€ per hour). The study was approved by Trinity College Dublin ethics committee and carried out in accordance with the Declaration of Helsinki, and EU GDPR. Written informed consent was given before the start of the first session.

2. 2. 2. Random Dot-Motion (RDM) Task

Participants completed the RDM testing in a sound-attenuated, darkened EEG booth. The task was presented on a 51cm CRT monitor (65.2 cd/m^2 luminance), 57cm from the participants, who sat in headrests to decrease movement and keep viewing distance consistent. The task was presented at a refresh rate of 75Hz on a screen with a resolution of 1024 x 768.

The random dot-motion direction task required participants to first report the direction of coherent movement and then report their confidence in that choice (see Fig. 2.2.2).

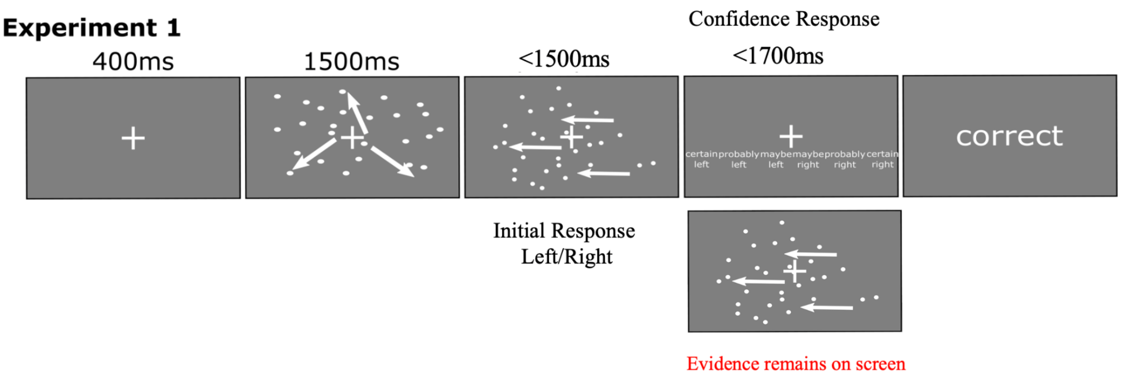


Figure 2.2.2 - Random Dot Motion Task*: The in-person experiment involved a random dot-motion discrimination task with direction and confidence reporting. Each trial began with a 1500 ms lead-in of incoherent motion to allow visual-evoked potentials related to stimulus onset to settle, providing a clearer view of choice-related signals. Participants first indicated the direction of motion - left or right - using the keyboard, with a response deadline of 1500 ms. The dots kept moving after the initial choice, and participants then reported their confidence on a 6-point scale while the stimulus remained on screen. The stimulus offset and feedback (correct/incorrect) followed the confidence response. No feedback was provided in the No-Feedback condition.*

Each trial began at the participant's own pace by pressing the space bar. A white fixation cross appeared at the center of the screen for 400 ms and remained visible throughout the trial until feedback was presented (or continuously in the no-feedback condition). The stimulus consisted of a random dot kinematogram (RDK) on a grey background, initially showing dots moving randomly (0% coherence) for 1500 ms. This lead-in was designed to minimize overlap between visual-evoked responses to stimulus onset and neural signals related to decision-making.

Following the lead-in, a subset of dots began moving coherently either to the left or right with equal probability. The coherence level (i.e., the proportion of coherently moving dots) was adjusted for each participant to ensure they achieved a specific level of accuracy (details provided below). Dot positions were updated on every frame: the coherent dots moved by 0.2° in their assigned direction, calculated relative to their position three frames earlier, producing an overall motion speed of 15°/s. The remaining (incoherent) dots were relocated randomly each frame. To prevent participants from tracking individual dots, the set of coherent dots was re-randomized every frame.

The onset of coherent motion occurred after an additional 800 ms of incoherent motion, after which participants had a 1500 ms window to make an initial left/right decision. Responses were made using the "c" key (left) or "n" key (right), pressed with the corresponding thumb, aligned with the direction of perceived motion.

For confidence reporting, participants rested the first three fingers of each hand on designated keys. Left-hand keys “1,” “2,” and “3” indicated “certain left,” “probably left,” and “maybe left,” respectively; right-hand keys “8,” “9,” and “0” corresponded to “maybe right,” “probably right,” and “certain right.” Participants were instructed to give their confidence judgment immediately after their initial decision. Only responses made within the 1700 ms confidence deadline were recorded. An important design feature is that the dot motion stimulus remained visible and continued to evolve throughout the confidence reporting window. This was a deliberate choice to enable post-decisional evidence accumulation: by continuing to provide perceptual evidence after the initial direction response, participants had the opportunity to revise their decision, as reflected in changes of mind (CoM). This design mirrors the paradigm employed by Grogan et al. (2023), in which post-decisional CPP dynamics index the continued accumulation of evidence between the initial response and the final confidence report. Maintaining the stimulus on screen thus allowed the current study to examine whether Moderates and Extremists differ in their capacity to integrate post-decision evidence - a question that would not be addressable if the stimulus were to disappear immediately after the initial response. It is also worth noting that this design differs slightly from some earlier studies (e.g., Rollwage et al., 2018) where confidence was reported after stimulus offset and therefore may reduce the opportunity for post-decisional updating and the likelihood of observing CoM effects.

All participants from both groups were equally allocated to a feedback and non-feedback condition (repeated measures, within-subject). This manipulation was tied to the dot motion task of the experiment. Feedback, if provided, appeared for 500 ms and included the response outcome (“correct,” “error,” “too fast,” or “too slow”), including a color cue: green for correct and red for incorrect. In the no-feedback condition, no performance feedback was shown; instead, the fixation cross turned purple after each response to signal the end of the trial.

The task had a total of 600 trials per participant and these were divided into four larger blocks of 150 trials each. Within each larger block, trials were further subdivided into three mini-blocks of 50 trials. So, participants completed 50 consecutive trials, followed by a short break, before continuing with the next mini-block. This procedure was repeated until all three mini-blocks (50 trials) within a larger block (150 trials) were completed.

Performance summaries (mean accuracy and points earned) were also shown at the end of each mini-block in the feedback condition. In the no-feedback condition, this “end-of-block feedback” was only shown after each larger block in order to maintain the participant’s motivation levels. A point system was implemented to increase motivation. Participants earned the most points when they made a correct initial response followed by the highest confidence rating (e.g., "certain left" or "certain right"). Points could also be lost for incorrect responses or for failing to respond within the designated time limits. More points were given for high-confidence than low-confidence initially correct responses, and at the same time, more points were given for low-confidence than high-confidence initially error responses. Additionally, participants had the opportunity to earn points through correct changes of mind: if their initial response was incorrect but their confidence rating correctly indicated the opposite direction (e.g., an incorrect initial choice of "left" followed by a correct confidence rating of "maybe," "probably," or "certain right"), they were rewarded.

Participants first completed a structured, multi-stage practice procedure designed to ensure task comprehension and stable performance before commencing the main experiment. The practice began with a walkthrough phase in which participants completed high-coherence (90%) trials requiring only the initial left/right direction judgment. This phase’s purpose was to familiarize them with the task layout, timing, and response requirements. Following this, the coherence of the dot motion was gradually decreased across trials, allowing participants to practice with more difficult stimuli. Difficulty was adjusted until participants were able to correctly identify the direction of motion at approximately 20% coherence. Once they were comfortable with the direction discrimination at this difficulty level, the confidence reporting phase was introduced. Participants were asked to perform both the initial direction judgment and the subsequent confidence rating. A longer response window was used for confidence reporting during this phase to reduce time pressure and support learning. Next, a staircasing procedure (QUEST) was implemented to estimate the motion coherence level at which each participant achieved around 70% accuracy on the initial direction judgment. This individualized threshold was then verified by having participants complete 30 additional trials at the determined coherence level. Adjustments were made if performance changed significantly from the target. Finally, participants completed a short block of trials without feedback to familiarize them with the neutral visual cues (e.g., the purple fixation cross) used in the no-feedback condition of the main experiment. This step was included to prevent confusion or surprise when transitioning into the main task.

The main EEG testing task took place right after the training portion and consisted of 4 blocks of 150 trials with 3 short rest breaks after 50 trials in between blocks. The feedback manipulation followed an alternating block design to control for potential carryover effects between feedback and no-feedback conditions: Block one and three were no-feedback blocks and Block two and four included feedback. All participants from both groups were equally designed to the feedback and non-feedback condition (repeated measures, within-subject). This fixed ordering was chosen over full counterbalancing for several reasons: First, the EEG signal quality can decline over the course of a session due to gradual increases in electrode–skin impedance and the increasing fatigue experienced by participants. A fixed block order also ensures that all participants experience the same mapping between session time and experimental condition, so that any session-related changes in signal quality are distributed equivalently across the feedback and no-feedback conditions at the group level. Second, a counterbalanced design would introduce the block order as an additional between-subjects factor, which would further reduce the statistical power in this study, which is already constrained by sample size. Third, the fixed alternating design controls for "time-on-task" effects by interleaving conditions rather than completing all no-feedback trials before all feedback trials (or vice versa). In fact, this allows to avoid the confounding of the feedback condition with general practice or fatigue effects that would arise from a blocked counterbalanced design. The no-feedback blocks were placed first and third so that participants encountered the neutral (no-feedback) context before and after the feedback context, reducing the risk of carry-over effects in which feedback-induced strategy changes impact the no-feedback behavior and EEG signal.

2.2.3 EEG acquisition and Pre-processing

The task was performed while 128-channel EEG was recorded using an ActiveTwo system (BioSemi), with a 512Hz sampling rate. Movements of the external eye musculature were recorded using two vertical electrooculogram (VEOG) electrodes placed above and below the left eye. Data were analysed using a combination of customised MATLAB scripts implemented using some features of the EEGLab toolbox (Delorme & Makeig, 2004). A low-pass filter at 40Hz was applied to the data and epoched in stimulus-locked intervals of -200ms to 1500 ms relative to evidence onset, initial-response-locked from -1000-3000ms around the initial response, final-response locked from -100ms to 250ms and feedback-locked from -200ms to 800ms. To allow accurate detection of slow-developing components like the CPP, a high-pass filter was not applied. Additionally, trials were baseline-corrected to a period after the initial zero-evidence stimulus appeared, but before the evidence appeared (200 ms before coherent motion onset). If a channel had extreme variance or high artefact counts, it was interpolated (Moderates mean = 5.12 channels, SD = 5.62; Extremes mean = 6.5 channels, SD = 5.13; range = 0-12). Initial bad channels were automatically flagged and reviewed through visual inspection, then interpolated on a per-block basis. Epochs were marked as artifacts and excluded if any scalp electrodes exceeded 100 μV or if the bipolar vertical EOG (VEOG) signal showed a voltage change greater than 200 μV between the baseline and response onset. Participants for whom more than 50% of trials were removed due to artifacts were excluded from further analysis (N = 3). On average, 517.4 out of 600 trials were retained for moderate's analysis and 514.25 trials for Extremists data analysis (Moderate: SD = 51.26, range = 399-580; Extremes: SD = 69.01, range = 284-584). To enhance spatial resolution, voltage data were converted to current source density (CSD) using the CSDToolbox (Kayser & Tenke, 2006) with default settings.

To isolate response-locked activity, data were aligned to the time of the initial motor response by using RIDE (Residue Iteration Decomposition). Behavioral and EEG measures of confidence and choice history were subsequently extracted for each participant. All final analyses, including the CPP, were calculated following this pre-processing pipeline, using epoched, CSD-transformed, and response-locked data.

2.2.4 Analysis Procedure

Statistical Analyses and plotting were performed using MATLAB. Trials with initial choice RTs less than 100 ms were excluded as they were too fast to have been informed by the physical evidence (missed trials Moderates = 2064 , missed trials Extremists = 2058). Since participants were allowed to revise their initial decision before providing a final confidence judgment, post-decision behavior and neural activity were interpreted in relation to both the initial and final responses. Changes of mind were measured behaviorally based on differences between the initial and final decision, and post-decision CPP was analyzed mainly as a function of initial choice accuracy (correct vs. incorrect), reaction time, and feedback condition. Final certainty ratings were used as behavioral outcome measures and reflected confidence in the final decision, irrespective of whether participants maintained or reversed their initial choice. Behavioral and electrophysiological analyses were conducted separately and were organized around the three preregistered hypotheses.

2.2.4.1 Behavioral Analysis Procedure

The behavioral data were analysed to quantify decision-making performance and metacognitive awareness. The dependent variables included reaction times (RTs), confidence reaction times (confRT), initial and final accuracy, confidence ratings, changes of mind (CoM), post-error slowing, confidence updating following feedback, behavioral correction (switching), and metacognitive sensitivity (AUC2). The distributions of initial reaction time and confidence reaction time were positively skewed and therefore log-transformed prior to the analysis. Initial accuracy was above chance consistently across all participants, and the confidence ratings scaled with response accuracy, which indicated an appropriate task engagement.

The behavioral analyses were conducted at both the trial level and participant level to capture both in-subject variability and group-level differences. All variables were defined consistently across participants, and any outliers or missing data were handled according to pre-registered criteria. The interactions, significant or not, are reported in the Results below.

2.2.4.2 Neural Analysis Procedure

The electrophysiological analyses focused on the centroparietal positivity (CPP) as a neural marker of evidence accumulation. EEG data were preprocessed by using current source density (CSD) transformation, and artefactual trials were excluded before averaging. The CPP was extracted from a predefined centroparietal electrode cluster (A4, A19, A5, A32, A20), which was identified based on the grand-average ERP topography for the time window from -170 ms to -50 ms preceding the initial choice response.

The CPP signals were analysed in multiple epochs: stimulus-locked, response-locked, post-decision (interpolated between the initial response and the confidence response), and feedback-locked. The pre-choice CPP amplitude was measured from −150 to −50 ms and CPP slope was measured -350 to -50 ms relative to the initial response. The stimulus-locked CPP amplitude was measured from 300 to 500 ms and CPP slope 200 to 500 ms after stimulus onset, while confidence-locked CPP's were measured from -150 to -50 ms (amplitude) and -250 to -50 ms (slope) prior to confidence response. Post-choice CPP dynamics were measured over the interval from the initial choice to the subsequent confidence response. EEG data were time-locked to the initial choice (0 ms) and analysed only up to the confidence response on a trial-by-trial basis. To account for the variability in inter-response intervals, post-decision CPP activity was time-normalised with linear interpolation (0–100% of the inter-response interval) and the peak amplitude (80-90% of the interval), mean amplitude (0-100%), and overall slope were extracted for analysis.
Feedback-locked CPP epochs were baseline-corrected using a −200 to 0 ms window and analysed over the 0–500 ms post-feedback interval (amplitude and slope). Measures extracted from CPP signals included mean amplitude, peak amplitude, and slope.

The following analyses were conducted at both the trial and participant levels to assess within-subject variability and group-level differences. Neural measures were examined as a function of initial choice accuracy, reaction time, and feedback condition.

2.2.5 Statistics

The in-person study used a 2 (Group: Moderates vs. Extremists) × 2 (Feedback: Present vs. Absent) mixed-design analysis to examine metacognitive awareness and neural data in decision-making. Specifically, we used a combination of ANOVAs and single-trial regression analyses, depending on the hypothesis being tested. The detailed tests used in each case are specified in the Results below. The experimental factor was a feedback/no-feedback manipulation.

2.3 Results

2.3.1 Behavioral Results

Despite implementing a difficulty titration procedure to ensure that participants started the main testing session performing the task at ~70% accuracy, Moderates did nevertheless have slightly higher accuracy levels over all than Extremists and the effect reached statistical significance (Moderates: $M = 0.729$, $SD = 0.055$; Extremists: $M = 0.718$, $SD = 0.051$; ($F(1, 25274) = 4.59$, $p = .032$, $\eta^2 = 0.00018$; *Figure 2.3.1: Panel G*). To investigate whether this difference could be explained by differences in task difficulty at the start, we compared the coherence level at the end of the titration phase between groups and observed no significance difference (Extremists: $M = 19.17$, $SD = 17.30$; Moderates: $M = 22.84$, $SD = 16.24$; $F(1, 47) = 0.587$, $p = 0.447$, $\eta^2 = 0.012$). Thus, the between-groups differences in accuracy are likely driven by larger learning effects in the Moderate group with extended task performance. A single-trial mixed-effects logistic regression on initial accuracy showed no significant effect of Feedback, but a statistically significant Group × Feedback interaction (Feedback: $F(1, 25274) = 5.57$, $p = 0.018$, $\eta^2 \approx 0.00022$; Group × Feedback interaction: $F(1, 25274) = 8.30$, $p = 0.004$, $\eta^2 \approx 0.00033$; *Figure 2.3.0: Group × Feedback for accuracy*). To further explore this interaction, we conducted a separate mixed-effects logistic regression within each group: Extremists exhibited a statistically significant increase in accuracy when feedback was provided that was not observed among the Moderates (Moderates: $F(1, 12934) = 2.91$, $p = 0.088$, $\eta^2 \approx 0.00023$; Extremists: $F(1, 12340) = 5.69$, $p = 0.017$, $\eta^2 \approx 0.00046$). Thus, contrary to our predictions, Extremists were actually more responsive to feedback

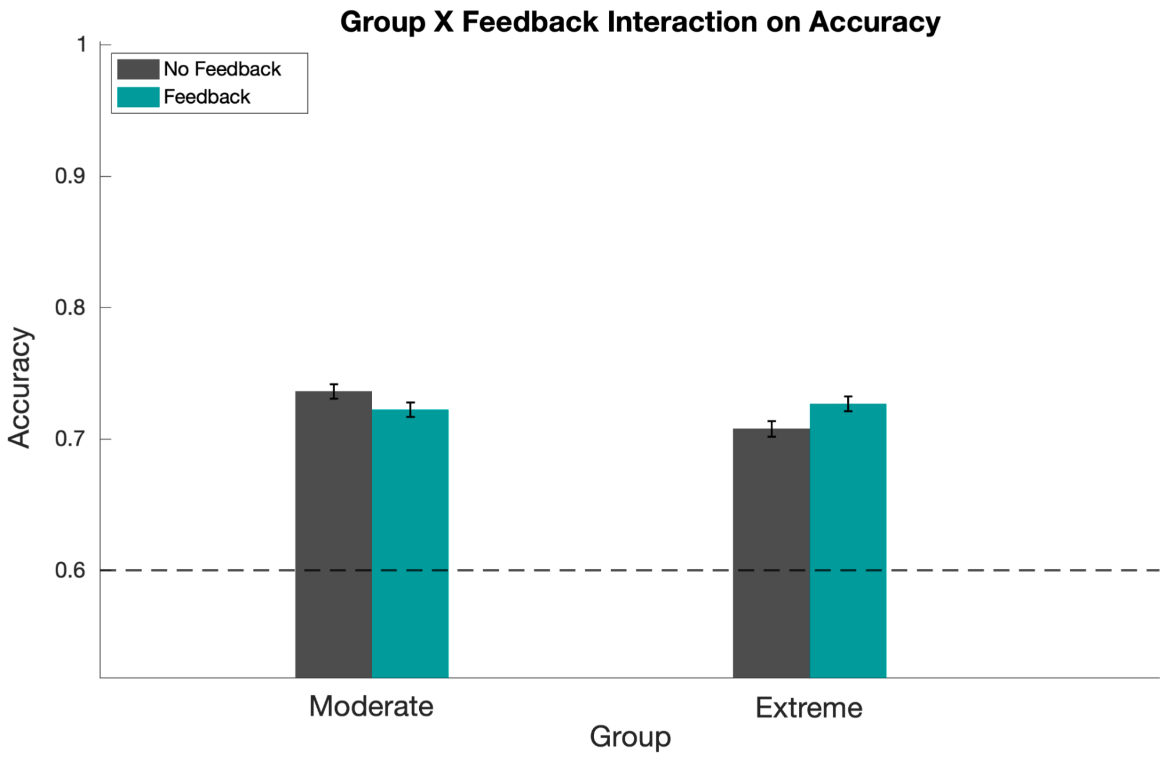


Figure 2.3.0: Group × Feedback for initial accuracy: Note: The horizontal dashed line marks the (minimum) 0.6 accuracy level and serves as a visual reference point, as the y-axis is truncated above 0.6 to better display the range of values observed across groups and conditions.

The confidence accuracy was similar across both groups (Moderates: M = 0.753, SD = 0.060; Extremists: M = 0.731, SD = 0.053; *Figure 2.3.1: Panel G*), as well as the number of missed trials per group (Moderates: 2064 misses; Extremists: 2058 misses).

Initial accuracy was also strongly related to participant's reaction time ($F(1, 25273) = 264.68$, $p < .001$, $\eta^2 \approx .01$), showing that faster responses were associated with lower accuracy. The feedback condition had a small effect on initial accuracy when accounting for reaction time ($F(1, 25273) = 5.37$, $p = .021$), with slightly higher accuracy in the Feedback condition. There was no main effect for Group or RT × Feedback interaction, so no meaningful interaction was observed.

Hypothesis 1: Extremists will exhibit cognitive rigidity (fewer changes of mind), lower meta-cognitive awareness (lower metacognitive efficiency score as measured by AUC2), reduced confidence thresholds. This will be reflected in the form of reduced decision-confidence calibration (mismatch between actual accuracy and reported confidence), lower choice reaction times, and higher confidence ratings despite lower accuracy (error trials) [...].

To test hypothesis 1, whether Extremists exhibit greater cognitive rigidity, lower metacognitive awareness, and reduced decision thresholds, we examined changes of mind (CoM), metacognitive efficiency (AUC2), overall confidence, confidence on error trials, and reaction times (RTs).

Contrary to our hypothesis, Extremists did not show greater cognitive rigidity with no effect of Group on CoM rates ($F(1, 47) = 0.179$, $p = .674$, $\eta^2 = .004$; *Figure 2.3.1: Panel A*). Additionally, although metacognitive efficiency (AUC2) was lower in Extremists than Moderates the effect did not reach statistical significance (Extremists: M = 0.585, SD = 0.054; Moderates: M = 0.596, SD = 0.050; $F(1, 47) = 0.642$, $p = 0.427$, $\eta^2 = 0.013$, *Figure 2.3.1: Panel B*). Opposite to what we hypothesized, Extremists had significantly slower RTs for their initial decisions compared to Moderates (Extermists: M = 906.9 ms, SD = 94.9; Moderates: M = 814.1 ms, SD = 132.1; ($F(1, 47) = 7.912$, $p = .007$, $\eta^2 = .144$, d = 0.791, *Figure 2.3.1: Panel E*). However, Extremists' final reaction time was faster compared to Moderates', but the difference did not reach statistical significance (Extremists: M = 243.8 ms, SD = 141.18; Moderates: M = 269.229 ms, SD = 105.412; $F = 0.51$, $p = 0.477$, $\eta^2 = 0.011$; *Figure 2.3.1: Panel F*). Together, these results do not support the predictions that Extremists would make faster decisions, have greater cognitive rigidity and lower metacognitive efficiency. Nevertheless, consistent with our hypothesis, we found that Extremists show overall higher confidence than Moderates (Extremists: M = 2.466, SD = 0.363; Moderates: M = 2.217, SD = 0.453; $F(1, 47) = 4.488$, $p = .039$, $\eta^2 = .087$, d = 0.596; *Figure 2.3.1: Panel C*), despite slightly lower accuracy in both the initial and final decisions. A repeated measures ANOVA with Accuracy (Correct vs Error) as a within-subject factor and Group as a between-subject factor confirmed that Extremists were generally more confident than Moderates and that all participants were more confident on correct than error trials. However, the Group X Accuracy interaction was not significant indicating that the higher confidence of Extremists was not specific to errors (Extremists: M = 2.306, SD = 0.313; Moderates: M = 1.862, SD = 0.304; Group: $F(1,47) = 55.22$, $p < 0.001$, $\eta^2 = 0.466$; Accuracy: $F(1,47) = 20.05$, $p < 0.001$, $\eta^2 = 0.299$; Group X Accuracy: $F(1,47) = 1.42$, $p = 0.24$, $\eta^2 = 0.029$; *Figure 2.3.1: Panel D*). However, the results do support our hypothesis that Extremists show higher confidence overall.

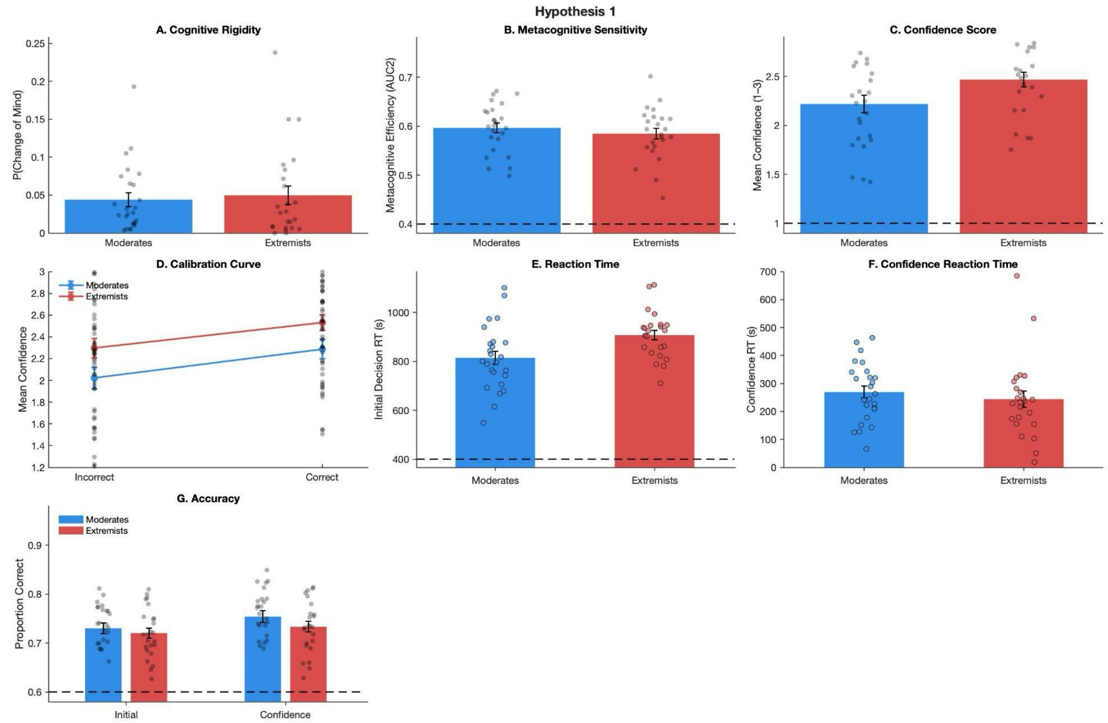


Figure 2.3.1: Behavioral results for Hypothesis 1: A: *Probability of changing one's mind (CoM), showing no significant difference between Moderates and Extremists.* ***B:*** *Metacognitive efficiency (AUC2), with similar sensitivity across groups.* ***C:*** *Overall confidence, with Extremists more confident than Moderates.* ***D:*** *Calibration curve showing mean confidence on correct and incorrect trials; error bars represent SEM.* ***E:*** *Mean initial decision reaction times, showing that Extremists were slower than Moderates.* ***F:*** *Confidence RTs, with no significant differences between groups.* ***G:*** *Accuracy for initial and confidence decisions, showing slightly lower accuracy in Extremists. Error bars in all panels indicate ±SEM. Individual participants are overlaid as scatter points. Color coding: blue = Moderates, red = Extremists.*

<u>Hypothesis 2:</u> Moderates will exhibit higher behavioral error detection rates than Extremists, as indicated by more frequent changes of mind or corrections after mistakes, post-error slowing (i.e., increased reaction time following an error), and overall lower confidence ratings, particularly in the non-feedback condition. [...].

In hypothesis two we predicted that, following initial choice mistakes, Moderates would show more frequent changes of mind, increased reaction times and lower confidence ratings, especially in the no-feedback condition. A one-way ANOVA showed no significant group differences in changes of mind on error trials, therefore both groups had comparable rates of behavioral error correction (Extremists: M = 0.127, SD = 0.141; Moderates: M = 0.135, SD = 0.106; CoM: $F(1, 47) = 0.056$, $p = 0.815$, $\eta^2 = 0.001$; *Figure 2.3.2 Panel A*). Both groups had a robust post-error slowing in initial reaction times of the trial following an error (Moderates: $t(24) = 3.54$, $p < .001$, $d = 0.179$; Extremists: $t(23) = 2.59$, $p < .017$, $d = 0.257$; *Figure 2.3.2: Panel B*), supporting an intact within-participant error sensitivity. A repeated-measures ANOVA showed that Extremists slowed significantly more than Moderates, opposing our hypothesis (Extremists: post-error RT: M = 924.12 ms, SD = 102.63, post-correct RT: M = 899.96 ms, SD = 94.07; Moderates: post-error RT: M = 833.00 ms, SD = 130.00, post-correct RT: M = 808.78 ms, SD = 135.17; $F(1,47) = 7.63$, $p = .008$, $\eta^2 = 0.140$). Because participants could reevaluate their initial incorrect choice with the confidence response, we examined confidence reaction time slowing within the same error trial as well, assuming that participants aware of an incorrect initial choice might slow down when making their subsequent confidence response. We did not find a significant difference between the group's confidence response reaction times following an error in their initial decision even though Extremists did show slightly faster post-error confidence reaction times compared to Moderates but the effect did not reach significance (Extremists: M = 272.62ms, SD = 155.58ms; Moderates: M = 301.48, SD = 117.55; $F(1, 47) = 0.540$, $p = .466$, $\eta^2 = .011$; *Figure 2.3.2: Panel C*). Lastly, we found that participants from both groups were significantly more confident with feedback than without (Extremists: $t(23) = 5.196$, $p = 0.000029$, $d = 1.061$; Moderates: $t(24) = 4.717$, $p = 0.000085$, $d = 0.943$). To examine whether the previously reported overall group difference in confidence (see Hypothesis 1) was modulated by feedback availability, we also analyzed confidence separately for Feedback and NoFeedback trials. The confidence ratings were higher overall in Extremists, with significant group differences in both NoFeedback (Extremists: M = 2.382, SD = 0.389; Moderates: M = 2.116, SD = 0.492; $F(1, 47) = 4.415$, $p = 0.041$, $\eta^2 = 0.086$, $d = 0.591$; *Figure 2.3.2: Panel D*) and Feedback conditions (Extremists: M = 2.546, SD = 0.353; Moderates: M = 2.311, SD = 0.439; $F(1, 47) = 4.238$, $p = 0.045$, $\eta^2 = 0.083$, $d = 0.579$; *Figure 2.3.2 : Panel D*). However, a 2 (Group) X 2 (NoFeedback/Feedback) repeated measures ANOVA on confidence ratings showed a non-significant interaction, indicating that the higher confidence of Extremists was not specific to feedback ($F(1,47) = 0.378$, $p = 0.542$, $\eta^2 = 0.008$).

Altogether, opposite to what we hypothesized, Moderates did not show higher behavioral error detection rates than Extremists, nor did they show greater post-error slowing, instead Extremists showed greater post-error slowing. However, the previously reported group difference in confidence (see Hypothesis 1) is persistent across Feedback and NoFeedback conditions:

Extremists remained more confident than Moderates, indicating that their higher confidence level is generally consistent, rather than being specific to one feedback type.

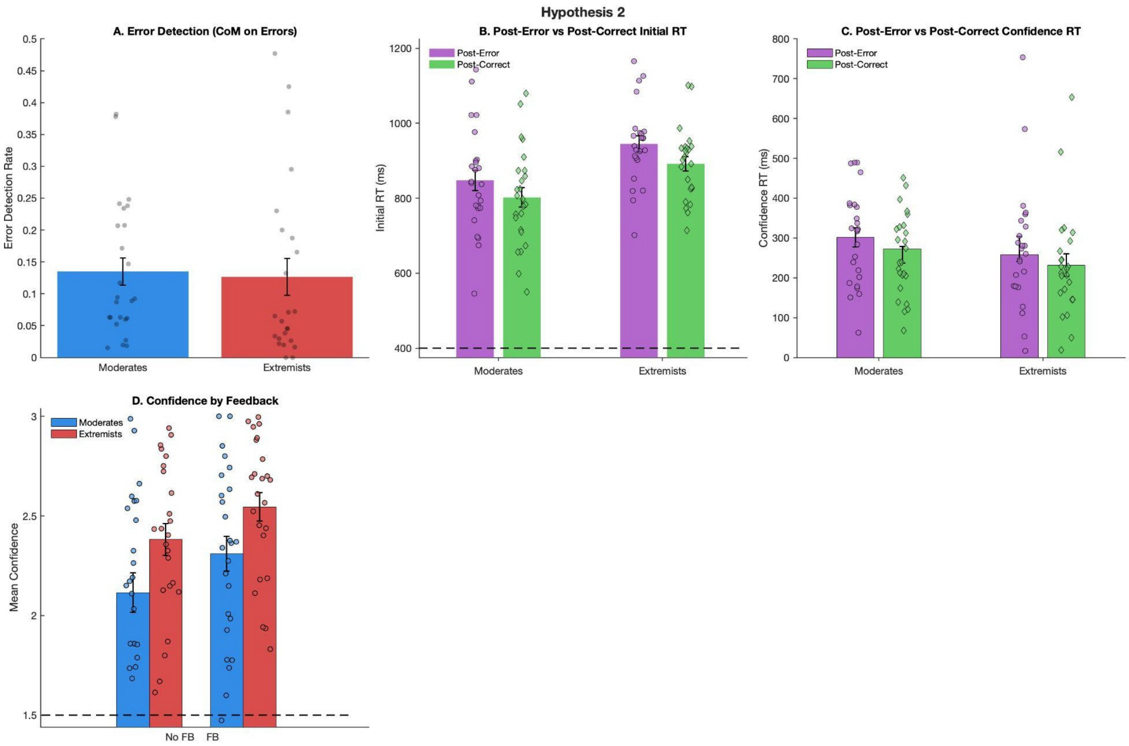


Figure 2.3.2: Behavioral results for Hypothesis 2: A: *Probability of changing one's mind (CoM) on error trials, showing no significant difference between Moderates and Extremists.* ***B:*** *Post-error vs Post-correct initial reaction times (RT), showing slightly more slowing in Extremists.* ***C:*** *Comparison of post-error versus post-correct confidence RTs, showing robust within-participant slowing for both groups after errors.* ***D:*** *Mean confidence by feedback condition (No-Feedback vs Feedback), showing higher confidence with feedback and generally higher confidence in Extremists. Error bars in all plots indicate ±SEM. Individual participants are overlaid as scatter points. Color coding: blue = Moderates, red = Extremists; purple = post-error, green = post-correct in plot D.*

<u>Hypothesis 3:</u> The feedback condition will increase error awareness and adaptive evidence accumulation in Moderates, while Extremists will show reduced neural and behavioral responsiveness to feedback, especially to disconfirmatory feedback. Specifically, in the feedback condition, Moderates will show [...] more adaptive decision adjustments (higher confidence updating, more CoMs, increased AUC2), [...]. Extremists will display [...] fewer behavioral corrections after disconfirmatory feedback.

Hypothesis three looked at how metacognitive behavior varied as a function of the presence or absence of feedback. We predicted that Moderates would show higher confidence updating, which refers to the change in participants' mean confidence when feedback was available compared to when it was absent. We also predicted more changes of mind (CoM) and increased AUC2 in the feedback condition, while Extremists would show fewer behavioral corrections after disconfirmatory feedback (switching behavior). We used an one-way ANOVA to compare Extremists and Moderates which showed no significant between-group differences in confidence updating in response to feedback (FB – NoFB: Extremists: $M = 0.163$, $SD = 0.154$; Moderates: $M = 0.195$, $SD = 0.207$; $F(1, 47) = 0.378$, $p = 0.542$, $\eta^2 = 0.008$; *Figure 2.3.3: Panel A*). Within-group comparisons indicated that both Moderates and Extremists significantly increased their confidence in response to feedback (Extremists: $t(23) = 5.196$, $p < 0.001$, $d = 1.061$; Moderates: $t(24) = 4.717$, $p < 0.001$, $d = 0.943$). A 2 (Group) × 2 (Feedback Condition) mixed ANOVA on changes of mind showed that the effect of feedback on CoM did not significantly differ between groups (i.e., no significant Group × Feedback interaction) (Extremists $M = 0.061$, $SD = 0.074$; Moderates $M = 0.058$, $SD = 0.058$; $F(1, 47) = 0.942$, $p = 0.337$, $\eta^2 = 0.0196$; *Figure 2.3.3: Panel B*). There was also no significant Group X Feedback interaction for metacognitive sensitivity, despite a slightly higher AUC2 in Moderates compared to Extremists (Extremists: $M = 0.596$, $SD = 0.061$; Moderates: $M = 0.602$, $SD = 0.052$; $F(1, 47) = 0.253$, $p = 0.6170$, $\eta^2 = 0.005$; *Figure 2.3.3: Panel C and D*). Lastly, we looked at the behavioral corrections after disconfirmatory feedback, which were quantified by assessing accuracy on the subsequent trial. To do so, we assessed participant's accuracy on trial t+1 as a function of whether trial t ended in disconfirmatory versus confirmatory feedback. A 2 (Group) x 2 (Disconfirmatory vs Confirmatory Feedback) mixed ANOVA showed no significant differences in behavioral corrections after disconfirmatory feedback (i.e. no significant interaction between Group X Feedback Type) (Extremists: $M = 0.670$, $SD = 0.136$; Moderates: $M = 0.690$, $SD = 0.080$; $F(1, 47) = 0.420$, $p = 0.5203$, partial $eta^2 = 0.0088$; *Figure 2.3.3: Panel E*). In fact, the results indicate that there is no group-specific "better" adjustment in decision making or corrections due to feedback, rejecting hypothesis three.

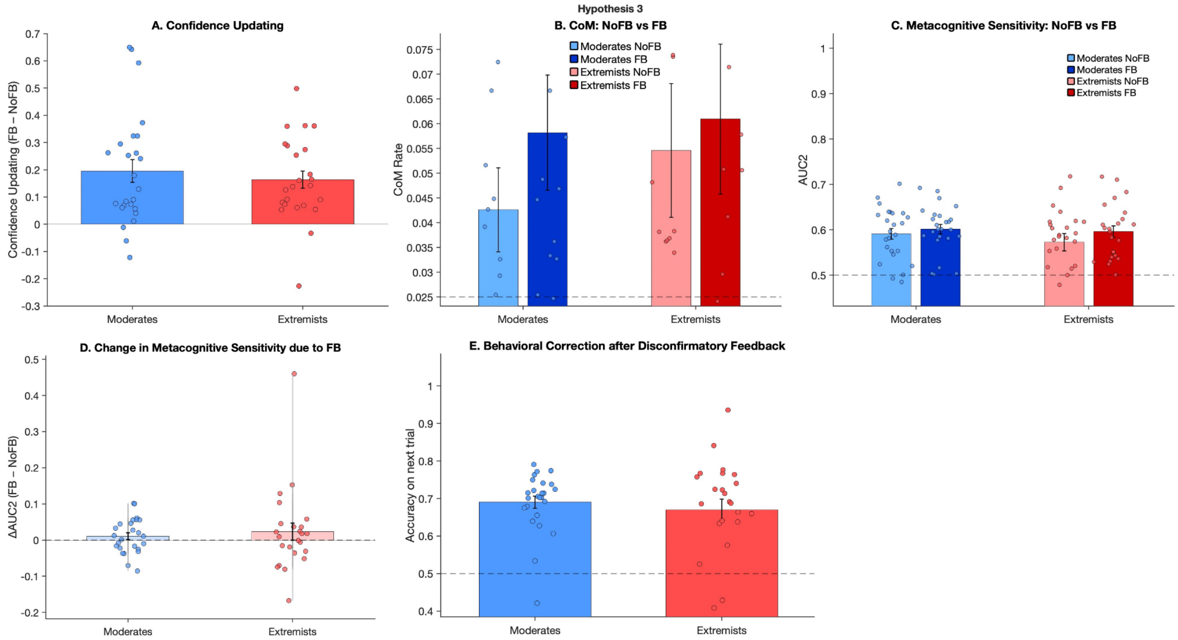


Figure 2.3.3: Behavioral results for Hypothesis 3: A: *Confidence updating (FB − NoFB), showing slightly better confidence updating for Moderates in the feedback condition, but no significant between-group difference.* ***B:*** *CoM by condition (NoFB vs FB), showing a significant within-group increase in Moderates but not Extremists, with no significant group × condition interaction.* ***C:*** *Metacognitive sensitivity (AUC2) in the feedback condition, showing slightly higher AUC2 in Moderates, but no significant difference between groups.* ***D:*** *Change in metacognitive sensitivity due to feedback (ΔAUC2 FB − NoFB), showing minimal and overlapping changes for both groups.* ***E:*** *Probability of switching/behavioral correction after disconfirmatory feedback, showing no significant between-group differences, with Moderates switching slightly less. Error bars in all plots indicate ±SEM. Individual participants are overlaid as scatter points. Color coding: blue = Moderates, red = Extremists; lighter/darker shades indicate no-feedback versus feedback condition*

2.3.2 Neural Results

Before testing the hypotheses, we verified the quality and consistency of CPP signals across participants and groups. CPPs were successfully extracted time-locked to stimulus onset, response, and confidence response, and grand-average waveforms confirmed robust centro-parietal deflections for all epochs and both groups (*Figure 2.3.4 Grand-average waveforms*). Topographic maps further verified the expected CPP distribution in Moderates and Extremists (*Figure 2.3.4 Topoplots*), indicating a proper signal localization. Together, these checks confirm that the neural markers of pre-decision, post-decision, and feedback-related evidence accumulation are reliable and suitable for the following hypothesis-driven analyses.

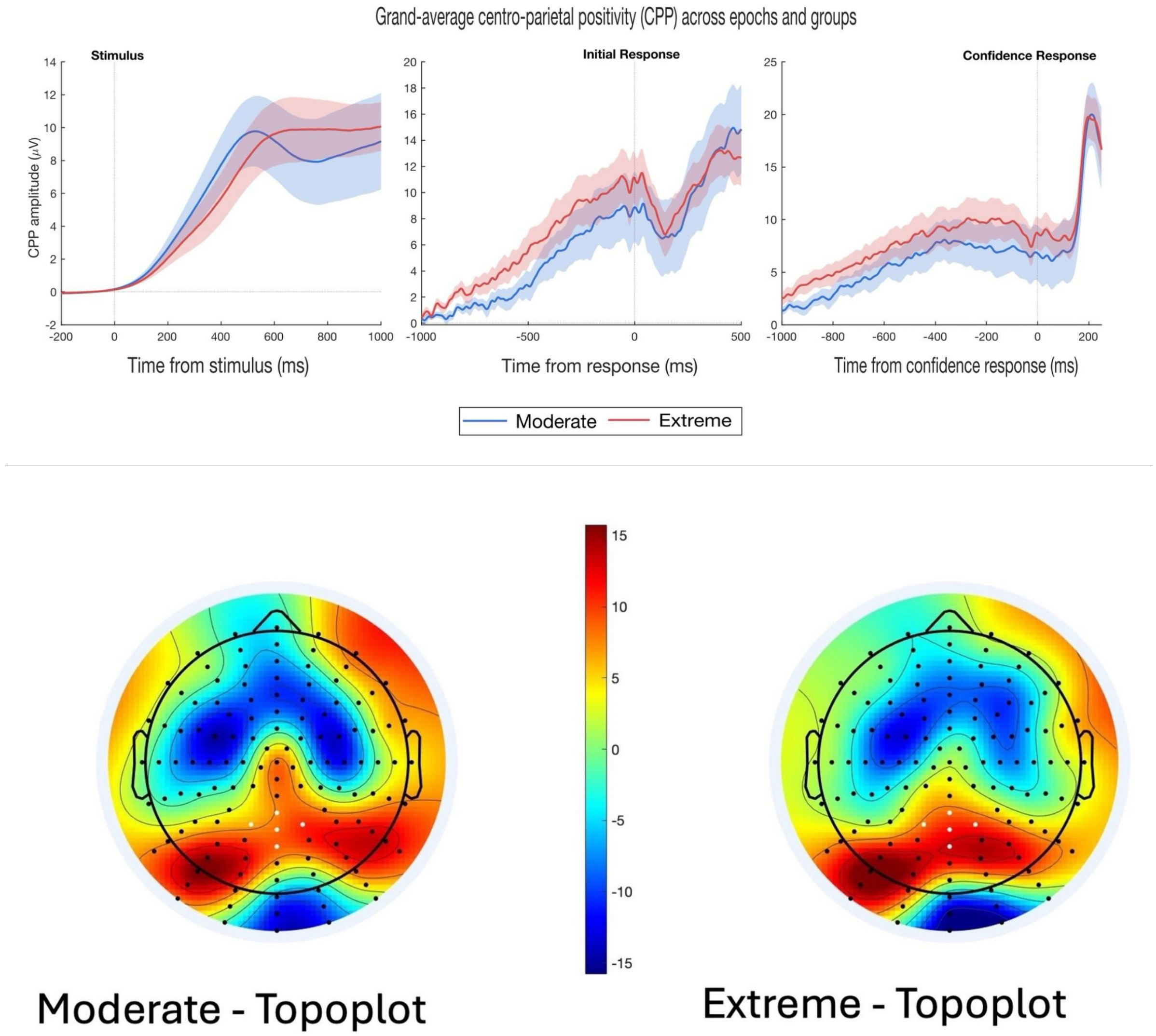


Figure 2.3.4: Grand-average waveforms. *Grand-average centro-parietal positivity (CPP) waveforms for Moderate (blue) and Extreme (red) participants. Shaded areas represent ±1 standard error of the mean (SEM) across participants. Plot 1 shows stimulus-locked CPPs aligned to stimulus onset (0 ms), Plot 2 shows response-locked CPPs aligned to initial response, and Plot 3 shows confidence-response-locked CPPs aligned to the participant's confidence report. Vertical*

dashed lines indicate time 0, and horizontal dashed lines indicate 0 μV. ***Topoplots.*** *Scalp topographies of the centro-parietal positivity (CPP) averaged across participants for Moderate (left) and Extreme (right) groups. Data represent mean EEG voltage in the pre-response window from −170 to −50 ms relative to the initial choice. Highlighted electrodes (white dots) indicate the centro-parietal cluster used for cluster-based analyses.*

Hypothesis 1: Extremists will show smaller CPP amplitudes before decisions, and less post-decision processing (post-choice CPP).

To test whether Extremists show smaller CPP amplitudes prior to decisions and less post-decisional processing, we looked at within-group differences between fast and slow trials, between-group differences across all trials, participant-level ANOVAs, mixed ANOVAs, and trial-level linear mixed-effects models (LME).

A 2X2 ANOVA with factors of Group and RT-bin confirmed that, as expected, CPP slope measured prior to initial response varied as a function of RT-bin ($F(1,47) = 12.87$, $p = 0.0007$, $\eta^2 = 0.215$). However, there was no significant main effect of Group on slope or on CPP amplitude, indicating that Extremists and Moderates did not differ in pre-decision CPP (CPP slope: $F(1,47) = 0.036$, $p = 0.850$, $\eta^2 = 0.0008$; CPP amplitude: $F(1,47) = 0.913$, $p = 0.344$, $\eta^2 = 0.019$). Trial-level LMEs corroborated these findings, with no significant Group effect on CPP slope ($F(1,25276) = 0.032$, $p = 0.857$, $\eta^2 < 0.0000$) or CPP amplitude ($F(1,25276) = 0.971$, $p = 0.324$, $\eta^2 < 0.0000$).

Therefore, H1 that Extremists would show smaller CPP amplitudes before initial decisions was not supported but the lack of a group difference in CPP slope or amplitude is noteworthy given the slower initial RTs and lower initial accuracy (*Figure 2.3.4 and Discussion*).

Post-decision CPP measures were also examined to assess potential group differences in post-decision processing. A One-way ANOVA found no significant group differences in post-decision CPP across mean amplitude, peak and slope (CPP mean: $F(1,47) = 0.302$, $p = 0.585$, $\eta^2 \approx 0.006$; CPP slope: $F(1,47) = 0.775$, $p = 0.383$, $\eta^2 = 0.016$; CPP peak: $F(1,47) = 0.030$, $p = 0.863$, $\eta^2 = 0.001$). Trial-level LMEs also did not show a significant effect of Group on post-decision CPP measures (CPP mean: $F(1,25276) = 0.307$, $p = 0.579$, $\eta^2 < 0.00001$; CPP slope: $F(1,25276) = 0.847$, $p = 0.357$, $\eta^2 < 0.00003$; CPP peak: $F(1,25276) = 0.030$, $p = 0.862$, $\eta^2 < 0.000001$). Thus, H1 that Extremists would show reduced post-decision CPP processing in

Extremists was also not supported, but instead, both groups showed similar pre and post-decision neural dynamics (*Figure 2.3.5*).

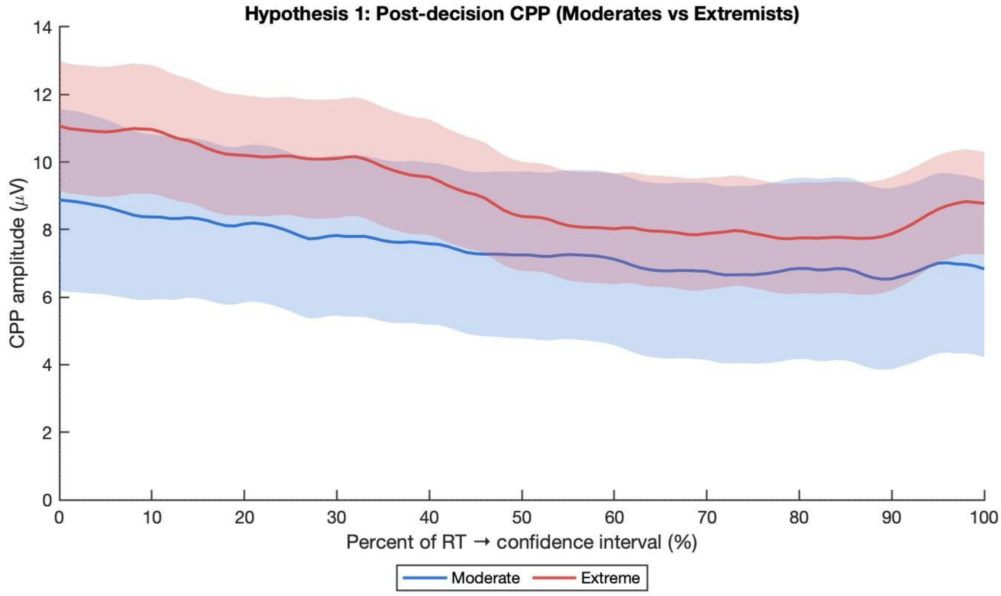


Figure 2.3.5: Post-decision CPP waveforms. *Grand-average post-decision centro-parietal positivity (CPP) waveforms for Moderate (blue) and Extreme (red) participants. Shaded areas represent ±1 standard error of the mean (SEM) across participants. The x-axis reflects the percentage of the interval from initial response to confidence response (0–100%), with 0% corresponding to the time of the initial response and 100% to the confidence report. Vertical dashed lines indicate the start of the interval (0%) and horizontal dashed lines indicate 0 μV. This plot visualizes the post-decisional CPP dynamics, highlighting differences in amplitude and slope between Moderate and Extreme participants.*

Hypothesis 2: Moderates will show greater post-decisional CPP amplitudes following errors and indicating the conscious awareness of mistakes, especially in the no-feedback condition.

In hypothesis 2, we predicted that Moderates will show greater post-decisional CPP amplitudes following errors, indicating stronger post-error processing. To test this, we examined CPP peak (80-90% of the interval) and mean amplitude (0-100%) and CPP slopes over the interpolated interval from the incorrect initial choice trials to the subsequent confidence response (post-decision epoch). A 2 (Group) x 2 (Error vs Correct Trial) mixed ANOVA showed that contrary to the hypothesis, CPP measurements did not differ significantly between Moderates and Extremists in error trials (*Table 2.3.6a*; Group X Trial Type: CPP peak $F(1,47) = 0.734$, $p = 0.396$, $\eta^2 = 0.015$, CPP Mean $F(1,47) = 0.799$, $p = 0.376$, $\eta^2 = 0.017$; CPP Slope $F(1,47) = 0.952$, $p = 0.334$, $\eta^2 = 0.019$; *Figure 2.3.6: Panel 1*).

Comparing feedback conditions within error trials only, Moderates exhibited stronger post-decision CPPs with feedback versus no-feedback, whereas Extremists showed smaller CPPs with feedback than without (*Table 2.3.6b*) but this effect did not reach statistical significance (Group X Feedback within error trials: CPP peak: $F(1,47) = 3.09$, $p = 0.085$, $\eta^2 = 0.062$; CPP mean: $F(1,47) = 2.943$, $p = 0.0928$, $\eta^2 = 0.059$; CPP slope: $F(1,47) = 1.333$, $p = 0.2542$, $\eta^2 = 0.028$; *Figure 2.3.6: Panel 2*). Overall, these results indicate that Moderates and Extremists have comparable post-decision CPP amplitudes and slopes following errors. Therefore, the hypothesis that Moderates would show greater Pe amplitude than Extremists, reflecting stronger conscious error awareness, was not supported. Both groups showed similar post-error neural dynamics.

Hypothesis 2: Post-decision (CPP) across Groups, Errors, and Feedback

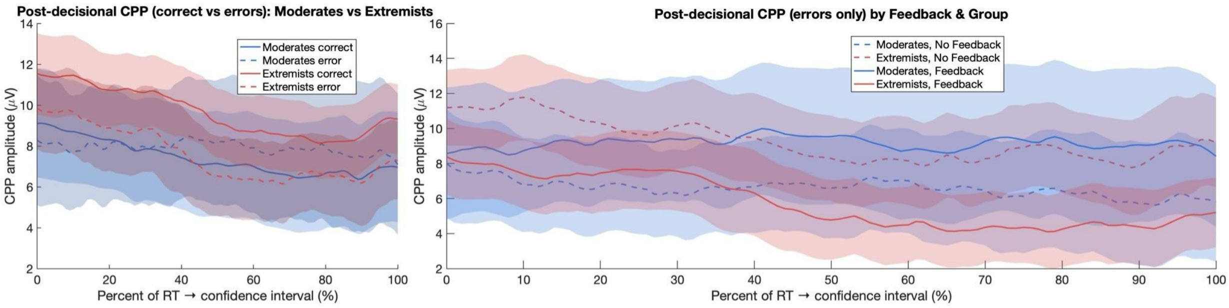
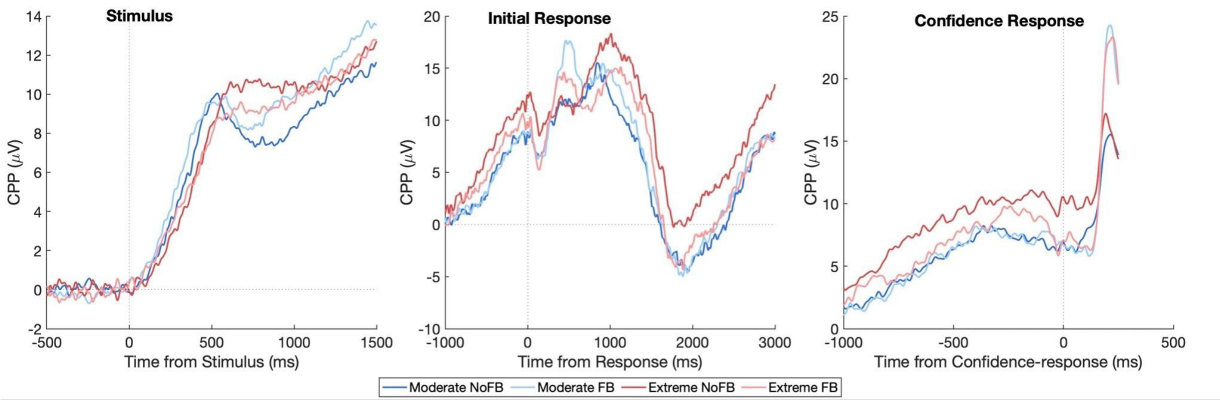


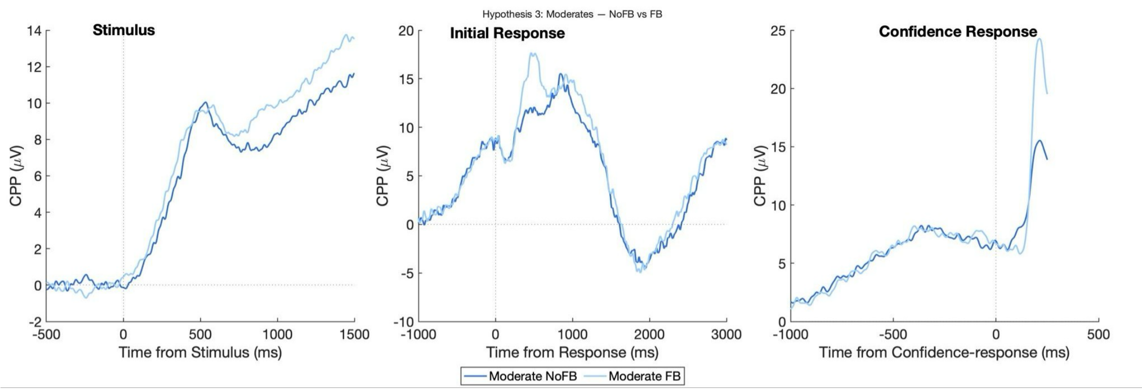
Figure 2.3.6: Post-decision CPP waveforms following errors. *Grand-average post-decision centro-parietal positivity (CPP) waveforms for Moderates (blue) and Extremists (red).* ***Panel 1*** *shows correct versus error trials for both groups, with shaded areas representing ±1 standard error of the mean (SEM).* ***Panel 2*** *overlays error trials separated by feedback condition, with dashed lines indicating No Feedback and solid lines indicating Feedback. The x-axis reflects the percentage of the interval from initial response to confidence response (0–100%), and the y-axis shows CPP amplitude in μV. This figure captures the post-decisional neural dynamics, showing amplitude and slope differences between Moderates and Extremists. Despite descriptively higher CPP amplitudes in Moderates, statistical analyses indicated no significant group differences in peak, mean, or slope of the post-decision CPP.*

<u>Hypothesis 3:</u> The feedback condition will increase adaptive evidence accumulation in Moderates, while Extremists show reduced neural [...] responsiveness to feedback, especially disconfirmatory feedback. Specifically, in the feedback condition, Moderates will show increased error-related processing (post-decision processing indexed by post-decision processing) [...], and enhanced evidence accumulation (greater CPP build-up). Extremists will display confirmation-biased neural processing of feedback, with blunted post-decision processing.

Lastly, to assess hypothesis 3, whether the feedback condition and type impact evidence accumulation across both groups differently, we analyzed 1) response-, stimulus-, confidence-, 2) post-decision interval and 3) feedback-locked CPP epochs. First, we started off with the response-, stimulus-, and confidence- locked epochs, measuring slope and amplitude differences across groups. A 2x2 mixed ANOVA did not find a significant effect of Feedback on evidence accumulation in both groups across any of the three epochs, except a significant interaction for the confidence-locked slope (Group X Feedback: Response-locked CPP slope $F(1,47)=0.042$, $p=0.8378$, $\eta^2=0.00$, CPP amplitude $F(1,47)=0.980$, $p=0.327$, $\eta^2=0.020$; Stimulus-locked CPP slope $F(1,47)=0.220$, $p=0.641$, $\eta^2=0.005$, CPP amplitude $F(1,47)=0.665$, $p=0.419$, $\eta^2=0.014$; Confidence-locked CPP slope $F(1,47)=4.708$, $p=0.0351$, $\eta^2=0.09$, CPP amplitude $F(1,47)=1.198$, $p=0.2793$, $\eta^2=0.025$). Follow-up paired t-tests showed that Moderates did not show a significant effect of Feedback in any epoch, whereas Extremists showed slightly decreasing evidence accumulation under Feedback, but only significantly in the confidence-locked epoch (**Extremists**: Response-locked slope t(23)=0.05, p=0.961, d=0.01; amplitude t(23)=-1.13, p=0.268, d=-0.23; Stimulus-locked slope t(23)=-1.17, p=0.252, d=-0.24; amplitude t(23)=-0.71, p=0.487, d=-0.14; Confidence-locked slope t(23)=-1.94, p=0.064, d=-0.40; amplitude t(23)=-1.50, p=0.147, d=-0.31; **Moderates**: Response-locked slope t(24)=0.29, p=0.775, d=0.058, *mean change=0.001*; amplitude t(24)=0.31, p=0.757, d=0.063, *mean change=0.37*; stimulus-locked slope t(24)=-0.57, p=0.571, d=-0.115, *mean change=-0.002*; amplitude t(24)=0.48, p=0.634, d=0.096, *mean change=0.49*; confidence-locked slope t(24)=1.11, p=0.278, d=0.222, *mean change=0.005*; amplitude t(24)=0.17, p=0.870, d=0.033, *mean change=0.26*). Nevertheless, no CPP metric supported our hypothesis that the feedback condition improves evidence accumulation in Moderates (*Figure 2.3.7*).

Hypothesis 3: Feedback-Condition CPP dynamics (Moderates vs Extremists)





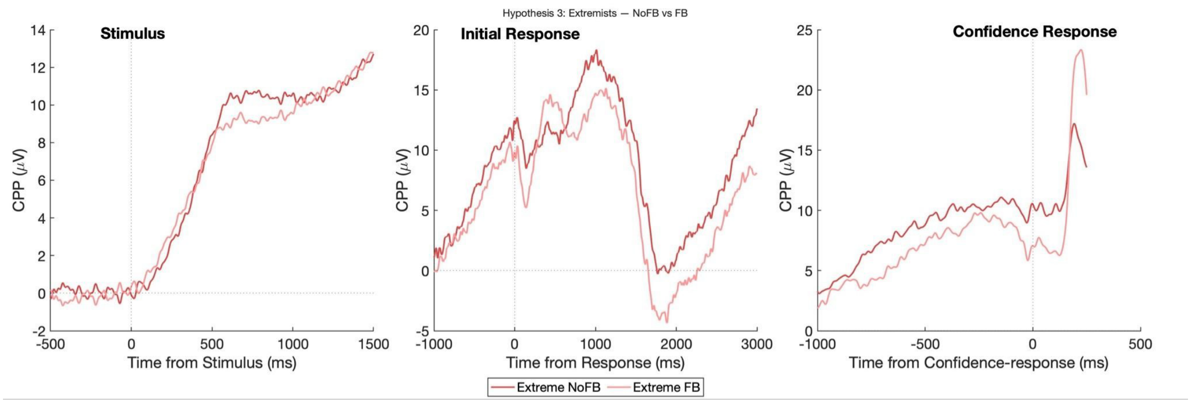


Figure 2.3.7: CPP stimulus-, response-, and confidence-response-locked in the Feedback versus No Feedback Condition. *Grand-average centro-parietal positivity (CPP) waveforms are shown for Moderates (blue) and Extremists (red).* ***Panel 1*** *overlays both groups, comparing No Feedback (darker lines) versus Feedback (lighter lines) trials across stimulus-, response-, and confidence-response-locked epochs (NOT feedback locked epochs).* ***Panel 2*** *isolates Moderates, comparing No Feedback and Feedback trials.* ***Panel 3*** *isolates Extremists, comparing No Feedback and Feedback trials. The x-axis represents time relative to stimulus onset, response, or confidence response (ms), and the y-axis indicates CPP amplitude (µV). All traces represent the grand mean across participants, without standard error shading. Both Moderates and Extremists show CPP differences in the feedback versus no-feedback blocks. However, these neural differences did not support enhanced adaptive evidence accumulation for Moderates in the feedback condition.*

We then moved on to analyzing the post-decision CPP to test whether Feedback enhances post-decision processing in Moderates, particularly after errors. For this, we used the interpolated CPP window from initial to confidence response. A 3-way mixed ANOVA (Group X Feedback X Initial Accuracy) showed no significant effect on post-decision processing for slope, peak and mean amplitude (CPP slope: $F(3,141)=0.228$, $p=.877$, $\eta^2=0.0048$; CPP peak: ($F(3,141)=1.496$, $p=.218$, $\eta^2=0.031$; CPP mean amplitude: $F(3,141)=1.577$, $p=.198$, $\eta^2=0.033$). Contrary to H3, feedback did not significantly enhance post-decision CPP in either Moderates or Extremists, including for error trials (*Figure 2.3.7*).

Additionally, we looked at a feedback locked epoch (epoched around feedback onset which is displayed after the confidence response), to test whether there are differences in neural responsiveness (evidence accumulation) directly during or after seeing the feedback (red or green fixation cross). A repeated measures ANOVA showed a significant main effect of Feedback but a non-significant Group × Feedback interaction (Feedback: CPP amplitude $F(1,47) = 7.756$, $p = 0.0077$, $\eta^2 = 0.142$, CPP slope $F(1,47) = 4.438$, $p = 0.041$, $\eta^2 = 0.086$; Group × Feedback: CPP amplitude $F(1,47) = 2.665$, $p = 0.109$, $\eta^2 = 0.054$, CPP slope $F(1,47) = 0.001$, $p = 0.555$, $\eta^2 = 0.011$; *Figure 2.3.8: Panel 5 and 6*). Overall, we did not find a significant interaction and therefore no statistical evidence that feedback-related neural responsiveness differed between Moderates and Extremists (*Figure 2.3.8: Panel 2*).

Lastly, we also looked at feedback-locked neural responsiveness to disconfirmatory versus confirmatory evidence (red versus green fixation cross). A 2 (Group) x 2 (Feedback Type) ANOVA did not find a significant Group X Feedback Type interaction for CPP slopes nor CPP amplitudes (CPP slope: $F(1,47) = 0.424$, $p = 0.518$, $\eta^2 = 0.006$; CPP amplitude: $F(1,47) = 1.364$, $p = 0.249$, $\eta^2 = 0.033$; *Figure 2.3.8: Panel 1*, *Panel 3, Panel 4*). This indicates that Extremists do not differ reliably from Moderates in neural responsiveness to disconfirmatory feedback. In conclusion, hypothesis 3 is not supported: there is no statistically significant evidence that Moderates show more adaptive evidence accumulation in the feedback condition while Extremists display confirmation-biased neural processing of feedback.

Hypothesis 3: Feedback-locked CPP dynamics across conditions and groups

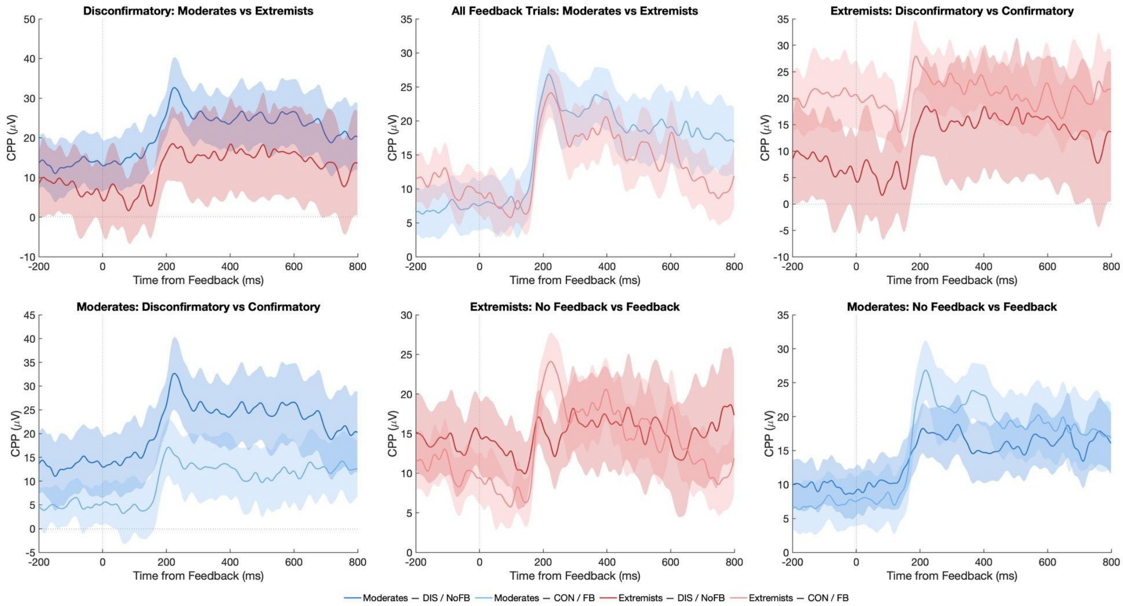


Figure 2.3.8: Feedback-locked CPP waveforms for Moderates and Extremists. *Grand-average feedback-locked centro-parietal positivity (CPP) waveforms are shown for Moderates (blue) and Extremists (red).* ***Panel 1*** *compares disconfirmatory trials between groups, with shaded areas representing ±1 standard error of the mean (SEM).* ***Panel 2*** *shows all feedback trials combined for both groups.* ***Panels 3 and 4*** *compare disconfirmatory versus confirmatory trials within Extremists and Moderates, respectively. Light (blue/red) represents confirmatory feedback.* ***Panels 5 and 6*** *contrast trials with no feedback versus feedback within Extremists and Moderates, respectively. Light (blue/red) represents the feedback condition. The x-axis reflects time from feedback onset (ms), and the y-axis shows CPP amplitude (μV). This figure captures group- and condition-specific post-feedback neural dynamics, showing differences in CPP amplitude and slope between Moderates and Extremists.*

2.4 Discussion

The present study investigated how politically more moderate versus more extreme individuals differ fundamentally in degrees of cognitive rigidity, metacognitive awareness, and feedback-related processing on a decision making task that is stripped of any political content. Perceptual decision making in different political groups has rarely been previously studied at the neural level, even though emerging behavioral research found reduced cognitive flexibility and metacognitive sensitivity, overconfidence, simplified information processing, and failing to update beliefs when presented with corrective evidence (Fleming & Daw, 2017; Rollwage et al., 2018; Zmigrod et al., 2019; Rollwage et al., 2020). The key area of interest was whether we could replicate these behavioral findings and more importantly, if these can be supported by neural measures of evidence accumulation additionally.

At the behavioral level, it was found that Extremists show an overall higher confidence across all trials. At the same time, the Extremists exhibited poorer primary task performance than Moderates with slower initial RTs and reduced accuracy suggesting that their elevated confidence reflects an overconfidence bias. This finding is compatible with results in other cognitive studies showing that political Extremists, on the left and right spectrum, tend to show higher levels of confidence (Van Proijen & Krouwel, 2019). Interestingly, we also found a difference in the way that the groups responded to feedback that ran counter to our expectations with only Extremists exhibiting improvements in their accuracy when feedback was provided. This finding could suggest that sensitivity to feedback may not be a fundamental problem for Extremists, contradicting previous work that has found radicals to assign undue probability to their initial decision rather than integrating new information (Rollwage et al., 2018). It could be that Extremists do better with feedback because it may help counteract their overconfidence bias. Without feedback, Extremists may be more likely to assume their decision making strategy is appropriate, and therefore rely on the external prompt that feedback provides to adjust their strategies. In fact, these results suggest that the source of feedback (e.g. who is giving feedback) may matter more in shaping decision-making in individuals with extreme beliefs and it suggests that sensitivity to feedback is context-dependent rather than a fundamental problem for Extremists. This idea aligns with previous research which showed that trial-by-trial feedback leads to strategic adjustments, reducing response bias and metacognitive distortions (Haddara & Rahnev, 2022). Moreover, our findings extend Haddara & Rahnev (2022) by showing that trial-by-trial feedback can also slightly improve accuracy specifically in overconfident participants, suggesting that the impact of feedback may depend on individual confidence or belief tendencies too. Aside from the overconfidence bias and the differences in primary task performance and feedback sensitivity, the Extremists did not exhibit any other behavioural differences. Contradictory to hypothesis 1, Extremists were not more cognitively rigid, nor did they show reduced metacognitive awareness.

Overall, these findings are not fully in line with previous studies (see Fleming & Daw, 2017; Rollwage et al., 2018; Zmigrod et al., 2019; Rollwage et al., 2020), which have reported differences in cognitive rigidity and metacognitive awareness between moderate and ideologically extreme individuals using similar tasks. In addition, our observation that Extremists had slower initial RTs contradicts the hypothesized 'hastiness' or 'impulsivity' that we expected to see. One possible explanation is that the screening procedures used in previous studies enabled researchers to recruit more extreme participants than in the present study. In fact, previous studies have collected participants from large online population samples (e.g., Mechanical Turk or Prolific) and indexed extremism dimensionally using multiple questionnaire-based measures that span the full ideological spectrum and traits such as willingness to fight for a group, die for a group, questionnaires about political issues, and self-reported political orientation (Rollwage et al., 2018; Zmigrod et al., 2019). However, in our study, we recruited locally, as it required in-person testing, so the groups were skewed toward university-based participants who are likely to represent a relatively small cross-section of the extremism scale. Moreover, we intended to pre-screen our participants with a survey that was relatively short and made it possible to find as many people as possible to complete it. Therefore, our survey had to be short and could not measure extremism tendencies as detailed and extensively as previous studies did. This constraint could have also limited the variability at the extreme ends of our sample's ideological distribution, such that individuals classified as "Extremists" here may represent a "milder" subgroup than those captured in online samples.

Additionally, methodological differences in the present study may account for discrepancies with previous findings. Participants in the present study reported confidence after committing to an initial choice, with the dot stimulus continuing to evolve on screen, thereby allowing additional evidence accumulation and the opportunity for changes of mind. This design differs slightly from earlier studies, in which confidence judgments were typically provided after stimulus offset. It could be that the continued evidence meant that even extremists were more likely to change their minds because there was objective evidence contradicting their initial choice. Perhaps it may only be when there is no further evidence provided that they are likely to show strong cognitive rigidity, as found in previous studies. Together with constraints in our sample collection, these task characteristics may have reduced sensitivity to the metacognitive impairment that have been previously observed in larger online studies. Rather than contradicting prior research, our findings suggest that cognitive markers of ideological extremism could be tied to both recruitment contexts and task demands, potentially mitigating markers of rigidity.

Moreover, prior research has often relied on traits associated with extremism, such as dogmatism, to recruit participants, as identifying extreme individuals directly can be biased by social desirability. In fact, Zmigrod et al. (2021) investigated perceptual correlates of ideological attitudes and found that dogmatism was associated with greater caution in perceptual decision making tasks and slower evidence accumulation. Therefore, our behavioral finding that Extremists show slower initial decision reaction times might reflect a more cautious decision making process or poorer encoding of evidence rather than cognitive rigidity or impulsivity. This challenges traditional ideas that associate ideological extremism with reduced deliberation.

Lastly, it's important to briefly discuss that metacognitive sensitivity was quantified by using the area under the Type 2 receiver operating characteristic curve (AUC2; Fleming & Lau, 2014). AUC2 was selected over alternative measures for several reasons. Unlike Type 2 d', AUC2 is a non-parametric measure that does not assume equal-variance Gaussian distributions of the underlying confidence signals, making it more robust to violations of this assumption that are common in trial-by-trial confidence data (Fleming & Lau, 2014). Compared to the model-based meta-d' measure (Maniscalco & Lau, 2012), AUC2 does not require repetitive model fitting and is therefore more stable when confidence ratings are unevenly distributed across bins, which is a concern in the present dataset, where some participants used only a restricted range of confidence responses. AUC2 values range from 0.5 (chance-level metacognition) to 1.0 (perfect metacognitive sensitivity). It should, however, be noted that AUC2, like other measures of metacognitive sensitivity, can covary with the first-order task performance: participants with higher accuracy tend to have a wider spread of evidence available to support accurate confidence judgments, which can inflate AUC2 independently of any true difference in metacognitive ability (Fleming & Lau, 2014). In the present study, Moderates showed slightly higher overall accuracy than Extremists, which represents a potential confound in between-group AUC2 comparisons. However, given that this accuracy difference was small and that the null AUC2 result goes in the direction opposite to that predicted (i.e., Extremists were not lower), it is unlikely that the accuracy difference drove the null metacognitive finding. Future work comparing metacognition between ideological groups should consider using meta-d'/d' (metacognitive efficiency), which explicitly accounts for between-group differences in first-order sensitivity and expresses metacognitive sensitivity as a ratio relative to d'. In fact, this would make it more appropriate for group comparisons where performance differs (Maniscalco & Lau, 2012).

At the neural level, while the CPP’s slope varied with initial reaction time in the manner that is usually observed and despite the Extremists having slower initial reaction times and lower accuracy, there were no significant group differences in pre-decision CPP slope or peak (initial and confidence response locked), post-decision CPP, or feedback related CPP dynamics. The lack of any group differences indicates that Extremists do not accumulate evidence differently or show less post-decisional processing at a neural level, opposing hypothesis 1. Further research will be required to test this hypothesis. Neural sensitivity to errors was not significantly different between groups either, contradicting hypothesis 2 and in line with the nonsignificant behavioral results. Within the error-focused analyses of H2, descriptive comparisons suggested that Moderates show numerically stronger post-decision CPPs with feedback, whereas Extremists showed the opposite pattern; however, these effects did not reach statistical significance and should be interpreted with caution. A weaker CPP in Extremists after errors, however, would align with previous studies that found confirmation bias in people with polarized beliefs and blunted processing of disconfirmatory evidence in individuals with higher confidence (Rollwage et al., 2020).

The neural results for hypothesis 3 led to an interesting finding, especially in light of our behavioral results: Extremists showed significant decreases in confidence-locked evidence accumulation in the feedback condition even though behaviorally, they improve their accuracy with feedback. What looks like a contradiction, may reflect a compensatory mechanism: feedback could counteract the overweighting of evidence in Extremists, leading to smaller CPP's. However, the feedback locked results for hypothesis 3 did not show a significant Group X Feedback interaction, disproving hypothesis 3 and a difference between groups in the neural processing of feedback. Therefore, we did not find enough support for a "choice bias" effect described by previous studies (Rollwage et al., 2018), in which radical individuals assign more weight to their initial choice rather than integrating new information. In fact, our neural data cannot confirm a tendency of Extremists to favor their own decisions or be biased towards new information. Overall, neural evidence accumulation did not differ between Extremists and Moderates significantly, and there was no significant evidence for group differences in feedback- or error-related processing.

Even though our results did not show significant group differences in CPP across more extreme and more moderate participants, this must be considered in the context of the behavioural differences that were observed. Previous work has repeatedly shown that larger CPPs are associated with faster RTs, increased accuracy and increased confidence (O'Connell & Kelly, 2021; Grogan et al 2023). Here, the Extremists exhibited numerically larger CPP waveforms despite slower initial RTs and lower accuracy. This points to a potential difference in the way that the CPP relates to behaviour in the Extremist group. One possibility is that Extremists generally over-weight evidence into their decision process so that a given piece of evidence will exert a larger influence over the final choice and confidence. This accords with a previous MEG study (Rollwage et al., 2020) which showed that overconfidence can drive a neural confirmation bias that downweights disconfirmatory evidence and amplifies confirmatory processing. Such an effect could potentially arise either from a “top-down” influence on the encoding of evidence in sensory areas or in its weighting at the stage of decision formation. It is also possible that the groups differed in their temporal weighting strategies, such as placing greater emphasis on early or choice consistent information. Further work should employ paradigms that are designed to measure evidence weighting strategies in order to investigate these trends in further detail.

Altogether, the present results suggest that politically more extreme attitudes could be associated with differences in confidence and feedback use at the behavioral level while differences in neural evidence accumulation are largely similar between groups. Behaviorally, Extremists consistently showed higher confidence despite poorer initial task performance, supporting the presence of an overconfidence bias. Importantly, Extremists also showed slight improvements in accuracy when trial-by-trial feedback was present which indicates that their sensitivity to feedback is not fundamentally impaired but may be context-dependent. This contrasts with previous accounts of ideological extremism that portray radical people as uniformly resistant to corrective information. Instead, our findings may suggest that explicit performance feedback may partially counteract overconfidence.

Neurally, perceptual evidence accumulation showed significant decreases in confidence-locked evidence accumulation in Extremists due to feedback, and visual inspection suggested modest differences in CPP generally, the study did not find any other significant CPP differences between Moderates and Extremists. In fact, the absence of group differences in CPP despite behavioral differences suggests that Extremists could have an altered weighting of evidence at the stage of decision formation, or differences in temporal integration strategies, such as putting a greater emphasis on early or choice-consistent information. In fact, all these mechanisms may also shape certainty and belief maintenance, a possibility that future research will need to confirm. In fact, while our present data cannot directly give an answer about these possibilities, the observed mismatch between CPP magnitude and behavioral performance in Extremists may suggest that ideological differences lie in the mapping between accumulated evidence and subjective decision evaluation. Future studies using tasks to specifically test evidence weighting and temporal integration will be necessary to directly test these mechanisms.

2.4.1 Limitations and Future Directions

Several limitations in the present study should be acknowledged. First, participants were recruited from a general population, largely university based, rather than specifically targeting individuals with highly polarized beliefs. Therefore, our sample may not capture the full spectrum of political extremism. Second, behavioral and neural measures were collected from a controlled perceptual decision-making task, which may not generalize our findings to real-world and political decision-making contexts. Third, the CPP results are difficult to interpret on their own as there are several potential reasons why they might arise. Future research could study other neural signatures of the decision process in order to elucidate the underlying processes. For example, mu/beta motor preparation signals would provide another means of testing whether the Groups differ in how cautious their decision-making strategy might be (e.g. a more cautious participant would be expected to show less motor preparation in mu/beta at evidence onset) versus whether the groups differ in how well they attend to (alpha-band power) and encode (SSVEP) the evidence. Another potential future direction could be to apply computational modeling approaches to dissociate evidence strength, decision thresholds, and post-decisional weighting. For example, using the DDM may differentiate Moderates from Extremists in terms of how quickly they integrate evidence and how much certainty they require before committing to a choice. Lastly, our relatively small sample size, due to time constraints, could have limited the power to detect group differences, especially for neural measures. Future studies could use larger samples or longitudinal designs to assess confidence biases and decision strategies over time, and to potentially find stronger effects than we did in the current study.

2.5 Conclusion

The primary aim of this thesis was to investigate whether people with more extreme political attitudes differ from Moderates in neural and behavioral perceptual decision making markers. Additionally, we investigated group differences in error awareness, metacognition, and responses to feedback and disconfirmatory evidence across neural and behavioral data. To date, research on political extremism has predominantly focused on ideological content, social identity and self-report measures rather than cognitive and neurophysiological measures. Previous cognitive findings suggest that the key parameters of more extreme individuals' decision processes reduced cognitive flexibility and metacognitive sensitivity, overconfidence, simplified information processing, and failing to update beliefs when presented with corrective evidence (Fleming & Daw, 2017; Rollwage et al., 2018; Zmigrod et al., 2019; Rollwage et al., 2020). The present study aimed to contribute a decision-neuroscience perspective to the study of political extremism, by measuring neural evidence accumulation in addition to the cognitive markers. Specifically, we aimed to test whether the cognitive differences found in previous studies would also be reflected at the level of perceptual decision formation and neural evidence accumulation.

The results provided limited support. At the behavioral level, Extremists did not show reduced metacognitive efficiency or cognitive rigidity. Contrary to expectations, Extremists showed slower initial reaction times compared to Moderates, suggesting a more cautious decision-making style or poorer encoding of evidence. This is consistent with more recent evidence that links dogmatism, an associated trait with extremism, to increased response caution (Zmigrod et al., 2021). Importantly, Extremists reported higher confidence across conditions, which aligns with previous studies that found a generalized confidence bias in more radical individuals (Van Proijen & Krouwel, 2019). In fact, Extremists consistently showed higher confidence despite poorer initial task performance, and across both feedback conditions and error trials. Moreover, behavioral results also showed slight improvements in accuracy when trial-by-trail feedback was provided which indicates, opposite to our hypotheses, that their sensitivity to feedback is not fundamentally impaired but eventually context-dependent. We did not find significant differences between the two groups in behavioral error corrections, post-error slowing, confidence updating in response to feedback, and behavioral correction following disconfirmatory feedback, were all comparable across groups.

At the neural level, the CPP signals were robust across participants, with significant decreases in confidence-locked evidence accumulation in Extremists in the feedback condition. Otherwise, the study did not find significant group differences in evidence accumulation, post-decisional dynamics, or error-related processing. Extremists did show consistently higher CPP amplitudes, while performing with lower decision accuracy, slower initial reaction time and greater subjective confidence. However, CPP differences did not reach significance. The results, therefore, do not provide evidence for significant group-specific CPP differences.

This has important theoretical implications. The findings only find tendencies that support the idea that political extremism is attributed to deficits in cognitive flexibility or processing information (Zmigrod et al, 2018; Zmigrod et al., 2019; Van Proijen & Krouwel, 2019). But more strongly our study supports models that propose a higher-order, top-down process to shape how evidence is evaluated and integrated into belief systems. This means, Extremists and Moderates may differ in how strongly they trust, endorse or maintain conclusions that are drawn from perceptual evidence. The absence of significant differences in CPP does not rule out biased information processing because it indexes the quantity of accumulated evidence rather than how evidence is weighted and interpreted based on prior beliefs. Moreover, the lack of group differences in CPP must be considered in line with the behavioral differences we did find in the present study: Extremists in the present study showed larger CPP waveforms despite their slower initial reaction times, reduced accuracy and overconfidence bias even though previous work has demonstrated that larger CPPs are associated with faster RTs, increased accuracy and increased confidence (O'Connell & Kelly, 2021; Grogan et al., 2023).

Applying EEG-based decision neuroscience methods to political cognition can provide contributions to the literature on extremism. The present study can show that null or counterintuitive results can still be theoretically informative. In fact, this highlights the need to differentiate between objective decision processes and subjective evaluative mechanisms when studying ideological rigidity.

In conclusion, the current study suggests that political extremism is associated with behavioral differences in confidence and feedback use. More extreme participants showed poorer initial task performance, and slower initial reaction times, indicating a more cautious decision-making style or poorer encoding of evidence, while they still maintained a consistently higher confidence level. This supports the presence of an overconfidence bias in Extremists. Importantly, Extremists also showed improvements in accuracy when trial-by-trail feedback was available which indicates that their sensitivity to feedback may be context dependent. Neural accumulation differences between groups did not reach significance, however, Extremists were consistently exhibiting higher CPP amplitudes despite their slower RTs and reduced accuracy. This reveals a dissociation between neural evidence accumulation and behavioral performance. This pattern highlights differences in how evidence is weighted and could point towards promising follow-up studies on evidence weighting, temporal integration and belief updating. Future work will also have to recruit a larger and more extreme sample for a replication study. Further work, including longitudinal, computational, and belief-relevant decision tasks will be necessary to determine how confidence biases interact with evidence accumulation over time and across ideological contexts. By investigating specific and closely linked cognitive processes to political extremism, future research may be better positioned to find interventions, reduce polarization and promote humility in increasingly divided societies.

References

Adorno, T. W., Frenkel-Brunswik, E., Levinson, D. J., & Sanford, R. N. (1950). *The authoritarian personality*. Harper.

Amodio, D. M., Jost, J. T., Master, S. L., & Yee, C. M. (2007). Neurocognitive correlates of liberalism and conservatism. *Nature neuroscience*, *10*(10), 1246–1247. https://doi.org/10.1038/nn1979

Bail, C. A., Argyle, L. P., Brown, T. W., Bumpus, J. P., Chen, H., Hunzaker, M. B. F., Lee, J., Mann, M., Merhout, F., & Volfovsky, A. (2018). Exposure to opposing views on social media can increase political polarization. *Proceedings of the National Academy of Sciences of the United States of America, 115*(37), 9216–9221. https://doi.org/10.1073/pnas.1804840115

Balconi, M., Acconito, C., Allegretta, R. A., & Crivelli, D. (2023). What Is the Relationship between Metacognition and Mental Effort in Executive Functions? The Contribution of Neurophysiology. *Behavioral sciences (Basel, Switzerland)*, *13*(11), 918. https://doi.org/10.3390/bs13110918

Briñol, P., & DeMarree, K. G. (2012). Social metacognition: Thinking about thinking in social psychology. In P. Briñol & K. DeMarree (Eds.), *Social metacognition* (pp. 1–18). Psychology Press. https://doi.org/10.4324/9780203865989

Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 65–116). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brycz, H., Konarski, R., Kleka, P., & Wright, R. (2019). The metacognitive self: The role of motivation and an updated measurement tool. *Economics and Sociology, 12*(1), 208–232. https://doi.org/10.14254/2071-789X.2019/12-1/12

Crist, R. E., Kapadia, M. K., Westheimer, G., & Gilbert, C. D. (1997). Perceptual learning of spatial localization: specificity for orientation, position, and context. *Journal of neurophysiology*, *78*(6), 2889–2894. https://doi.org/10.1152/jn.1997.78.6.2889

Deolankar, V., Fong, J., & Sriram, S. (2024). Content generation on social media: The role of negative peer feedback. *SSRN*. https://ssrn.com/abstract=4522092

Dieffenbach, M. C., Gillespie, G. S. R., Burns, S. M., McCulloh, I. A., Ames, D. L., Dagher, M. M., Falk, E. B., & Lieberman, M. D. (2021). Neural reference groups: a synchrony-based classification approach for predicting attitudes using fNIRS. *Social cognitive and affective neuroscience, 16*(1-2), 117–128. https://doi.org/10.1093/scan/nsaa115

Echelmeyer, L., Slotboom, A.-M., & Weerman, F. (2023). The putative effect of identity on extremist radicalization: A systematic review of quantitative studies. *Studies in Conflict & Terrorism*. Advance online publication. https://doi.org/10.1080/1057610X.2023.2247621

Efklides, A. (2001). Metacognitive experiences in problem solving: Metacognition, motivation, and self-regulation. In A. Efklides, J. Kuhl, & R. M. Sorrentino (Eds.), *Trends and prospects in motivation research* (pp. 297–323). Dordrecht, Netherlands: Kluwer Academic Publishers.

Fernbach, P. M., Rogers, T., Fox, C. R., & Sloman, S. A. (2013). Political extremism is supported by an illusion of understanding. *Psychological science*, *24*(6), 939–946. https://doi.org/10.1177/0956797612464058

Flavell, J. H. (1987). Speculations about the nature and development of metacognition. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 21–29). Hillsdale, NJ: Lawrence Erlbaum Associates.

Fleming, S. M., & Lau, H. C. (2014). How to measure metacognition. *Frontiers in Human Neuroscience, 8*, 443. https://doi.org/10.3389/fnhum.2014.00443

Fleming, S. M., & Daw, N. D. (2017). Self-evaluation of decision-making: A general Bayesian framework for metacognitive computation. *Psychological Review, 124*(1), 91–114. https://doi.org/10.1037/rev0000045

Fleming, S. M., van der Putten, E. J., & Daw, N. D. (2018). Neural mediators of changes of mind about perceptual decisions. *Nature Neuroscience, 21*(4), 617–624. https://doi.org/10.1038/s41593-018-0104-6

Fleming, S. M. (2024). Metacognition and confidence: A review and synthesis. *Annual Review of Psychology, 75,* 241–268. https://doi.org/10.1146/annurev-psych-022423-032425

Forstmann, B. U., Ratcliff, R., & Wagenmakers, E.-J. (2016). Sequential sampling models in cognitive neuroscience: Advantages, applications, and extensions. *Annual Review of Psychology, 67*, 641–666. https://doi.org/10.1146/annurev-psych-122414-033645

Galli, G., Sirota, M., Materassi, M., Zaninotto, F., & Terry, P. (2017). Brain indices of disagreement with one's social values predict EU referendum voting behavior. *Social Cognitive and Affective Neuroscience, 12*(11), 1758–1765. https://doi.org/10.1093/scan/nsx105

Geers, M., Fischer, H., Lewandowsky, S., & Herzog, S. M. (2024). The political (a)symmetry of metacognitive insight into detecting misinformation. *Journal of*

Experimental Psychology: General, 153(8), 1961–1972. https://doi.org/10.1037/xge0001600

Grogan, J. P., Rys, W., Kelly, S. P., & O'Connell, R. G. (2023). Confidence is predicted by pre- and post-choice decision signal dynamics. *Imaging Neuroscience, 1*, 1–23. https://doi.org/10.1162/imag_a_00005

Haddara, N., & Rahnev, D. (2022). The Impact of Feedback on Perceptual Decision-Making and Metacognition: Reduction in Bias but No Change in Sensitivity. *Psychological science*, *33*(2), 259–275. https://doi.org/10.1177/09567976211032887

Hogg, M. A., & Reid, S. A. (2006). Social identity, self-categorization, and the communication of group norms. *Communication Theory, 16*(1), 7–30. https://doi.org/10.1111/j.1468-2885.2006.00003.x

Hogg, M. A. (2012). Uncertainty-identity theory. In P. A. M. Van Lange, A. W. Kruglanski, & E. T. Higgins (Eds.), *Handbook of theories of social psychology* (pp. 62–80). Sage Publications Ltd. https://doi.org/10.4135/9781446249222.n29

Hohendorf, M., & Bauer, M. (2023). Metacognitive sensitivity and symptoms of mental disorder: A systematic review and meta-analysis. *Frontiers in Psychology, 14,* 991339. https://doi.org/10.3389/fpsyg.2023.991339

Howard, T. (2025). Inside the Radicalized Mind: The Neuropolitics of Terrorism and Violent Extremism. *Cambridge: Cambridge University Press*.

Ionescu, T. (2012). Exploring the nature of cognitive flexibility. *New Ideas in Psychology, 30*(2), 190–200. https://doi.org/10.1016/j.newideapsych.2011.11.001

Iqbal, M., O'Brien, K. S., & Bliuc, A. M. (2022). The relationship between existential anxiety, political efficacy, extrinsic religiosity and support for violent extremism in

Indonesia. *Studies in Conflict & Terrorism, 47*(11), 1510–1521. https://doi.org/10.1080/1057610X.2022.2034221

Jacobs, J. E., & Paris, S. G. (1987). Children's metacognition about reading: Issues in definition, measurement, and instruction. *Educational Psychologist, 22*(3–4), 255–278. https://doi.org/10.1207/s15326985ep2203&4_4

Jiang, L., Yang, C., Pi, Z., Li, Y., Liu, S., & Yi, X. (2023). Individuals with high metacognitive ability are better at divergent and convergent thinking. *Journal of Intelligence, 11*(8), 162. https://doi.org/10.3390/jintelligence11080162

Judd, C. H. (1905). Practice without knowledge of results. *The Psychological Review: Monograph Supplements, 7*(1), 185–198.

Kanai, R., Feilden, T., Firth, C., & Rees, G. (2011). Political orientations are correlated with brain structure in young adults. *Current biology : CB*, *21*(8), 677–680. https://doi.org/10.1016/j.cub.2011.03.017

Katabi, N., Simon, H., Yakim, S., Ravreby, I., Ohad, T., & Yeshurun, Y. (2023). Deeper than you think: Partisanship-dependent brain responses in early sensory and motor brain regions. *Journal of Neuroscience, 43*(6), 1027–1037. https://doi.org/10.1523/JNEUROSCI.0895-22.2022

Kelly, S. P., & O'Connell, R. G. (2013). Internal and external influences on the rate of sensory evidence accumulation in the human brain. *The Journal of Neuroscience, 33*(50), 19434–19441. https://doi.org/10.1523/JNEUROSCI.3355-13.2013

Kim, J. H., Kim, C. M., & Yim, M. S. (2020). An investigation of insider threat mitigation based on EEG signal classification. *Sensors, 20*(21), 6365. https://doi.org/10.3390/s20216365

Kirschner, H., Humann, J., Derrfuss, J., Danielmeier, C., & Ullsperger, M. (2021). Neural and behavioral traces of error awareness. *Cognitive, Affective & Behavioral Neuroscience, 21*(3), 573–591. https://doi.org/10.3758/s13415-020-00838-w

Kruglanski, A. W., Gelfand, M. J., Bélanger, J. J., Sheveland, A., Hetiarachchi, M., & Gunaratna, R. (2014). The psychology of radicalization and deradicalization: How significance quest impacts violent extremism. *Political Psychology, 35*, 69–93. http://www.jstor.org/stable/43783789

Liu, J., Dosher, B., & Lu, Z. L. (2014). Modeling trial-by-trial and block feedback in perceptual learning. *Vision Research, 99*, 46–56. https://doi.org/10.1016/j.visres.2014.01.001

Liu, C., Wang, K., & Yu, R. (2024). The neural representation of metacognition in preferential decision-making. *Human brain mapping*, *45*(6), e26651. https://doi.org/10.1002/hbm.26651

Lord, C. G., Ross, L., & Lepper, M. R. (1979). Biased assimilation and attitude polarization: The effects of prior theories on subsequently considered evidence. *Journal of Personality and Social Psychology, 37*(11), 2098–2109. https://doi.org/10.1037/0022-3514.37.11.2098

Luo, T., & Liu, C. (2023). The impact of feedback on metacognition: Enhancing in easy tasks, impeding in difficult ones. *Consciousness and Cognition, 116*, 103601. https://doi.org/10.1016/j.concog.2023.103601

Maniscalco, B., & Lau, H. (2012). A signal detection theoretic approach for estimating metacognitive sensitivity from confidence ratings. *Consciousness and cognition, 21*(1), 422–430. https://doi.org/10.1016/j.concog.2011.09.021

Maniscalco, B., & Lau, H. (2014). Signal detection theory analysis of type 1 and type 2 data: Meta-d′, response-specific meta-d′, and the unequal variance SDT model. In S. M. Fleming & C. D. Frith (Eds.), *The cognitive neuroscience of metacognition* (pp. 25–66). Springer.

Mulder M. J. (2014). The temporal dynamics of evidence accumulation in the brain. *The Journal of neuroscience: the official journal of the Society for Neuroscience*, *34*(42), 13870–13871. https://doi.org/10.1523/JNEUROSCI.3251-14.2014

Murphy, P. R., Robertson, I. H., Allen, D., Hester, R., & O'Connell, R. G. (2012). An electrophysiological signal that precisely tracks the emergence of error awareness. *Frontiers in Human Neuroscience, 6*, 65. https://doi.org/10.3389/fnhum.2012.00065

Németh, D., Vékony, T., Orosz, G., Sarnyai, Z., & Zmigrod, L. (2024). The interplay between subcortical and prefrontal brain structures in shaping ideological belief formation and updating. *Current Opinion in Behavioral Sciences, 55,* 101385. https://doi.org/10.1016/j.cobeha.2024.101385

O'Connell, R. G., Dockree, P. M., Bellgrove, M. A., Kelly, S. P., Hester, R., Garavan, H., Robertson, I. H., & Foxe, J. J. (2007). The role of cingulate cortex in the detection of errors with and without awareness: A high-density electrical mapping study. *European Journal of Neuroscience,* *25*(8), 2571–2579. https://doi.org/10.1111/j.1460-9568.2007.05477.x

O'Connell, R. G., Dockree, P. M., & Kelly, S. P. (2012). A supramodal accumulation-to-bound signal that determines perceptual decisions in humans. *Nature Neuroscience, 15*(12), 1729–1735. https://doi.org/10.1038/nn.3248

O'Connell, R. G., & Kelly, S. P. (2021). Neurophysiology of human perceptual decision-making. *Annual Review of Neuroscience, 44*, 495–516. https://doi.org/10.1146/annurev-neuro-092019-100200

Osorio T, H., & Reyes M, G. (2025). Decision Making in Moral Judgment Context is Modulated by Individual Metacognition. *Psychological reports*, *128*(4), 2846–2865. https://doi.org/10.1177/00332941231191067

O'Leary, A. P., & Fletcher, W. (2024). Thinking about Believing: Can Metacognitive Reflection Encourage Belief Updating?. *Journal of Intelligence*, *12*(5), 47. https://doi.org/10.3390/jintelligence12050047

Ozer, S., & Bertelsen, P. (2018). Capturing violent radicalization: Developing and validating scales measuring central aspects of radicalization. *Scandinavian journal of psychology*, *59*(6), 653–660. https://doi.org/10.1111/sjop.12484

Paris, S. G., & Winograd, P. (1990). How metacognition can promote academic learning and instruction. In B. F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 15–51). Lawrence Erlbaum Associates, Inc.

Pedersen, W. S., Muftuler, L. T., & Larson, C. L. (2018). Conservatism and the neural circuitry of threat: Economic conservatism predicts greater amygdala–BNST connectivity during periods of threat vs. safety. *Social Cognitive and Affective Neuroscience, 13*(1), 43–51. https://doi.org/10.1093/scan/nsx133

Petrov, A. A., Dosher, B. A., & Lu, Z.-L. (2006). Perceptual learning without feedback in non-stationary contexts: Data and model. *Vision Research, 46*(19), 3177–3197. https://doi.org/10.1016/j.visres.2006.03.022

Pyszczynski, T., Greenberg, J., & Solomon, S. (1999). A dual-process model of defense against conscious and unconscious death-related thoughts: an extension of terror management theory. *Psychological review*, *106*(4), 835–845. https://doi.org/10.1037/0033-295x.106.4.835

Rabbitt, P. M. A. (1966). Errors and error correction in choice-response tasks. *Journal of Experimental Psychology, 71*, 264–272. https://doi.org/10.1037/h0022853

Rokeach, M. (1948). Generalized mental rigidity as a factor in ethnocentrism. *The Journal of Abnormal and Social Psychology, 43*(3), 259–278. https://doi.org/10.1037/h0056134

Rokeach, M. (1960). *The open and closed mind: Investigations into the nature of belief systems and personality systems*. Basic Books.

Rollwage, M., Dolan, R. J., & Fleming, S. M. (2018). Metacognitive Failure as a Feature of Those Holding Radical Beliefs. *Current biology : CB*, *28*(24), 4014–4021.e8. https://doi.org/10.1016/j.cub.2018.10.053

Rollwage, M., Loosen, A., Hauser, T. U., Moran, R., Dolan, R. J., & Fleming, S. M. (2020). Confidence drives a neural confirmation bias. *Nature Communications, 11*(1)*,* 2634. https://doi.org/10.1038/s41467-020-16278-6

Salvi, C., Barr, N., Dunsmoor, J. E., & Grafman, J. (2023). Insight problem solving ability predicts reduced susceptibility to fake news, bullshit, and overclaiming. *Thinking & Reasoning, 29*(4), 760–784. https://doi.org/10.1080/13546783.2022.2146191

Seow, T. X. F., Fleming, S. M., & Hauser, T. U. (2025). Metacognitive biases in anxiety-depression and compulsivity extend across perception and memory. *PLOS Mental Health, 2*(3), e0000259. https://doi.org/10.1371/journal.pmen.0000259

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review, 7*(4), 351–371. https://doi.org/10.1007/BF02212307

Schreiber, D., Fonzo, G., Simmons, A. N., Dawes, C. T., Flagan, T., Fowler, J. H., & Paulus, M. P. (2013). Red brain, blue brain: Evaluative processes differ in Democrats and Republicans. *PLoS ONE, 8*(2), e52970. https://doi.org/10.1371/journal.pone.0052970

Schulz, L., Rollwage, M., Dolan, R. J., & Fleming, S. M. (2020). Dogmatism manifests in lowered information search under uncertainty. *Proceedings of the National Academy of Sciences of the United States of America, 117*(49), 31527–31534. https://doi.org/10.1073/pnas.2009641117

Schwartz, B. L., & Metcalfe, J. (1994). Methodological problems and pitfalls in the study of human metacognition. In J. Metcalfe & A. P. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 93–113). The MIT Press.

Skitka, L. J. (2010). The psychology of moral conviction. *Social and Personality Psychology Compass, 4*(4), 267–281. https://doi.org/10.1111/j.1751-9004.2010.00254.x

Stankov, L., Saucier, G., & Knezevic, G. (2010). Militant extremist mindset: Proviolence, vile world, and divine power. *Psychological Assessment, 22*, 70–8

Stanton, J. D., Sebesta, A. J., & Dunlosky, J. (2021). Fostering Metacognition to Support Student Learning and Performance. *CBE life sciences education*, *20*(2), fe3. https://doi.org/10.1187/cbe.20-12-0289

Sternberg, R. J. (2003). Wisdom and education. *Educational Psychologist, 17*(3), 253–263. https://doi.org/10.1177/026142940301700304

Tanner, K. D. (2012). Promoting student metacognition. *CBE—Life Sciences Education, 11*(2), 113–120. https://doi.org/10.1187/cbe.12-03-0033

Tetlock, P. E. (1986). A value pluralism model of ideological reasoning. *Journal of Personality and Social Psychology, 50*(4), 819–827. https://doi.org/10.1037/0022-3514.50.4.819

van den Berg, R., Anandalingam, K., Zylberberg, A., Kiani, R., Shadlen, M. N., & Wolpert, D. M. (2016). A common mechanism underlies changes of mind about decisions and confidence. *eLife, 5*, e12192. https://doi.org/10.7554/eLife.12192

Van Hiel, A., Onraet, E., Crowson, H. M., & Roets, A. (2016). The relationship between right‐wing attitudes and cognitive style: A comparison of self‐report and behavioural measures of rigidity and intolerance of ambiguity. *European Journal of Personality, 30*(6), 523–531. https://doi.org/10.1002/per.2082

van Prooijen, J.-W., & Krouwel, A. P. M. (2016). Extreme political beliefs predict dogmatic intolerance. *Social Psychological and Personality Science, 8*(3), 292–300. https://doi.org/10.1177/1948550616671403

van Prooijen, J.-W., & Krouwel, A. P. M. (2019). Psychological features of extreme political ideologies. *Current Directions in Psychological Science, 28*(2), 159–163. https://doi.org/10.1177/0963721418817755

Webber, D., Babush, M., Schori-Eyal, N., Vazeou-Nieuwenhuis, A., Hettiarachchi, M., Bélanger, J. J., Moyano, M., Trujillo, H. M., Gunaratna, R., Kruglanski, A. W., & Gelfand, M. J. (2018). The road to extremism: Field and experimental evidence that significance loss-induced need for closure fosters radicalization. *Journal of personality and social psychology*, *114*(2), 270–285. https://doi.org/10.1037/pspi0000111

Weise, D. R., Pyszczynski, T., Solomon, S., Greenberg, J., & Kosloff, S. (2008). Interpersonal politics: The role of terror management and attachment processes in shaping political preferences. *Psychological Science, 19*(5), 448–455. https://doi.org/10.1111/j.1467-9280.2008.02108.x

Wells, A., & Fisher, P. (2016). Metacognitive therapy: Theoretical background and model of depression. In A. Wells & P. Fisher (Eds.), *Metacognitive therapy for depression* (pp. 144–168). Wiley. https://doi.org/10.1002/9781119114482.ch6

Yeung, N., & Summerfield, C. (2012). Metacognition in human decision-making: Confidence and error monitoring. *Philosophical Transactions of the Royal Society B: Biological Sciences, 367*(1594), 1310–1321. https://doi.org/10.1098/rstb.2011.0416

Zmigrod, L., Rentfrow, P. J., & Robbins, T. W. (2018). Cognitive underpinnings of nationalistic ideology in the context of Brexit. *Proceedings of the National Academy of Sciences of the United States of America, 115*(19), E4532–E4540. https://doi.org/10.1073/pnas.1708960115

Zmigrod, L., Rentfrow, P. J., & Robbins, T. W. (2019). Cognitive inflexibility predicts extremist attitudes. *Frontiers in Psychology, 10,* 989. https://doi.org/10.3389/fpsyg.2019.00989

Zmigrod, L. (2020). The role of cognitive rigidity in political ideologies: Theory, evidence, and future directions. *Current Opinion in Behavioral Sciences, 34,* 34–39. https://doi.org/10.1016/j.cobeha.2019.10.016

Zmigrod, L., Rentfrow, P. J., & Robbins, T. W. (2020). The partisan mind: Is extreme political partisanship related to cognitive inflexibility?. *Journal of experimental psychology. General*, *149*(3), 407–418. https://doi.org/10.1037/xge0000661

Zmigrod, L., Eisenberg, I. W., Bissett, P. G., Robbins, T. W., & Poldrack, R. A. (2021). The cognitive and perceptual correlates of ideological attitudes: a data-driven approach.

Philosophical transactions of the Royal Society of London. Series B, Biological sciences, *376*(1822), 20200424. https://doi.org/10.1098/rstb.2020.0424

Zmigrod, L. (2021). A neurocognitive model of ideological thinking. *Politics and the Life Sciences, 40*(2), 224–238. https://doi.org/10.1017/pls.2021.10

Zmigrod, L., & Goldenberg, A. (2021). *Cognition and emotion in extreme political action: Individual differences and dynamic interactions*. Current Directions in Psychological Science, 30(3), 245–252. https://doi.org/10.1177/0963721421993820

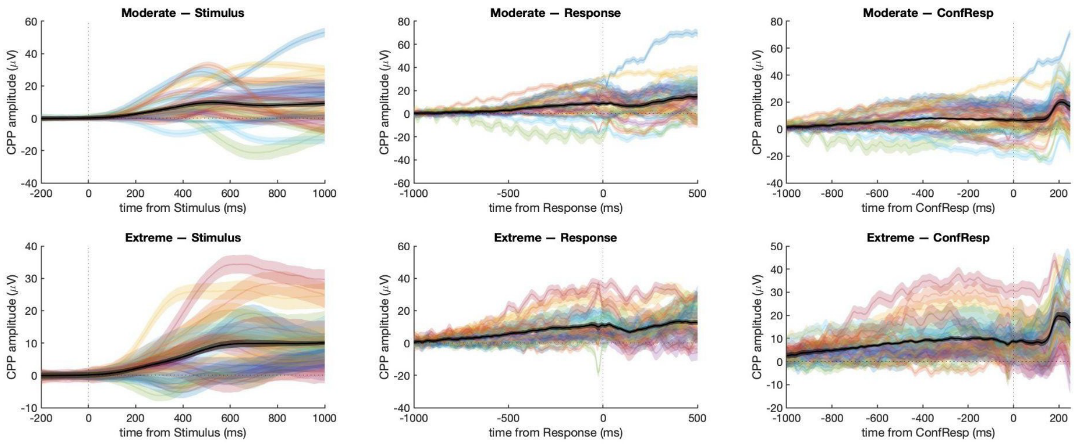


Figure 2.3.4b: Individual and grand-average CPP waveforms across groups. *This figure separates groups into columns, allowing visualization of participant-level variability and the consistency of CPP dynamics within each group. Vertical dashed lines represent time 0 (stimulus, response, or confidence response), and horizontal dashed lines indicate 0 μV. Individual participant waveforms are shown with low opacity, and the bold black line represents the group average.*

Participant Consent Form

TRINITY COLLEGE
Institute of Neuroscience
TCIN *from molecules to mind*

Consent Form

TITLE OF STUDY: EEG study Investigating the relationship between meta-Cognition and Political Beliefs
There are four sections in this form. Each section contains a number of statements. You are asked to write your initials in the box beside the statement if you agree. If you do not agree with a statement, please leave the box blank. The end of this form is for the researchers to complete. **Please ask the researchers <u>any</u> questions you may have when reading each of the statements.** **Thank you for participating.**

GENERAL	**Participant Initials**
I confirm I have read and understood the **Information Leaflet** for the above-named study. The information has been fully explained to me and I have been able to ask questions, all of which have been answered to my satisfaction.	
I understand that participation in this study **is entirely voluntary, and if I decide that I do not want to take part, I can stop taking part in this study at any time without giving a reason.**	
I understand that I **will be paid €10 per hour in TangoCard vouchers or receive one Research Credits per half hour of participation in this study.**	
I know how to contact the research team if I need to.	
I agree to being contacted by researchers by email as part of this research study.	
I agree to take part in this research study having been fully informed of the **risks, benefits and alternatives** which are set out in full in the information leaflet which I have been provided with.	

DATA PROCESSING	**Participant Initials**
I give my permission for my data to be processed in line with the aims of the research study, as outlined in the information leaflet.	
I understand that, under the Freedom of Information Act (2014), I can have access to any identifiable information the study team stores about me, if requested.	
I understand that the personal information collected in the study will be kept strictly confidential and will only be made available to qualified scientists who are part of the study team. Data will be anonymised meaning there will be no link between the data and your identity. Therefore, the only personal information is the name and signature on this consent form. The consent form will be kept in a locked cabinet only accessible to named researchers.	
I understand that **I can withdraw my permission to take part in this study at any time up until the data are anonymised at the end of this testing session** without giving a reason. I understand that in this case, the researchers will delete all information related to me and I will be removed from the study. I understand that after **the end of the testing session**, I will no longer be able to withdraw or access my study information, as all links between the study data and my identity will be destroyed. If I wish to withdraw, I am to inform the lead researcher and/or their supervisor and they will delete any of my data that has been collected and remove me from the study (contact details for the researchers are provided below).	
I understand that confidentiality may be breached in circumstances in which; 1. The research team has a strong belief or evidence exists that there is a serious risk of harm or danger to either the participant or another individual. This may relate to issues surrounding physical, emotional and/or sexual abuse, concerns for child protection, rape, self-harm, suicidal intent or criminal activity. 2. Disclosure is required as part of a legal process or Garda investigation. In such instances, information may be disclosed to significant others or appropriate third parties without permission being sought. Where possible, a full explanation will be given to the participant regarding the necessary procedures and also the intended actions that may need to be taken.	

RETENTION OF RESEARCH SAMPLES FOR FUTURE RESEARCH	**Participant Initials**
I understand that **fully anonymised data** (which has had all identifying information about me removed) will be retained for a period of 3.5 years by the study team as per Trinity College Dublin requirements.	

SHARING OF INFORMATION	Participant Initials
I give permission for my data to be shared with the scientific community and the general public via a fully open database on the internet. ***<u>I understand that my data will be fully anonymised before sharing - no personally identifying data will be shared</u>***. I understand that data shared in this way will be accessible to researchers and members of the public anywhere in the world, not just the EU. I understand that by sharing data in this way, my data might be used for other, future research projects in addition to the study I am currently participating in. Those future projects can focus on any topic and might be completely unrelated to the goals of this study. I understand that once the data are shared, ***<u>they cannot be destroyed, withdrawn, or recalled, because they can no longer be linked with me</u>***. I understand that it is possible that some of the research conducted using my shared information eventually could lead to the development of new research methods, new diagnostic tests, new drugs, or other commercial products. I understand that should this occur, there is no plan to provide me, the study team, or TCD with any part of the profits generated from such products, nor will I, the study team, or TCD have any ownership rights in the products.	

Participant Name (Block Capitals) Participant Signature Date

Witness Name (Block Capitals) Witness Signature Date

To be completed by the Principal Investigator or nominee:

I, the undersigned, have taken the time to fully explain to the above participant the nature and purpose of this study in a way that they could understand. I have explained the risks and possible benefits involved. I have invited them to ask questions on any aspect of the study that concerned them.

I have given a copy of the information leaflet and consent form to the participant with contacts of the study team

Researcher name:

Title and qualifications:

Signature:

Date:

Contact Details:

If you have any further questions about this study please do not hesitate to contact a member of the research team or the Data Protection Officer:

Dr. Redmond O' Connell - Supervisor
Professor,
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Telephone: 01 896 4543
Email: reoconne@tcd.ie

Paula Geiser
Postgraduate Psychology Student,
Trinity College Institute of Neuroscience,
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Email: geiserp@tcd.ie

Data Protection Officer
Secretary's Office,
Trinity College Dublin,
Dublin 2.
dataprotection@tcd.ie
www.tcd.ie/privacy

Demographic Form

Demographic Questionnaire

Participant Identifier: ____________________________________

Date of Participation: ____________________________________

Gender: ____________________________________

Age (Years & Months): ____________________________________

Level of Education: --

Handedness (Left/Right): ____________________________________

Have you ever been diagnosed with any neurological illness or injury, for example epilepsy, concussion including explained or unexplained loss of consciousness, dementia or Parkinson's disease?:

Are you currently taking any medications for psychiatric conditions such as depression or anxiety?:

Are you currently suffering from, recovering from or receiving treatment for drug or alcohol abuse?:

TRINITY COLLEGE
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Information Sheet

“EEG study Investigating the relationship between meta-Cognition and Political Beliefs”

Research Team:

Dear Participant,

Thank you for considering participation in our study. My name is Paula Geiser, and I am a master’s student in Prof. O’Connell’s Lab. Before you decide whether or not you wish to take part, please read this information sheet carefully. Please feel free to ask the experimenter any questions you may have. Don’t feel rushed or under pressure to make a quick decision. You should understand the risks and benefits of taking part in this study so that you can make a decision that is right to you.

What is the Project? We invite you to participate in a study investigating the neural mechanisms underlying perceptual decision-making. These fundamental cognitive processes occur constantly in daily life, involving the interpretation of sensory information, its retention over time, and its application in decision-making and actions. For example, noticing a traffic light, recognizing that it is green, and deciding to proceed; or briefly seeing a sign warning of ice on the road and remembering to drive more cautiously along that stretch.
Through this study, we aim to gain insight into the brain's strategies when making decisions based on sensory information. Additionally, previous research suggests

that decision-making processes may vary among individuals with different political orientations. This study seeks to explore whether such differences are reflected at the neural level within a perceptual decision-making task.

Inclusion criteria

There are no risks associated with any of the procedures in neurologically healthy individuals. However, in order to take part in the study you must meet the following criteria. If you cannot confirm any of the conditions listed below, please inform the researcher.

1. I am 18 years or older
2. I have normal or corrected-to-normal vision
3. I do not suffer from migraines or bad headaches
4. I have never suffered from epilepsy and I am not sensitive to flashing stimuli
5. I have no personal or family history of unexplained fainting
6. I am not currently taking medication that primarily acts on brain chemistry (e.g. anti-depressants)
7. I have no personal history of neurological or psychiatric illness or brain injury

Am I allowed to withdraw?

As participation is completely voluntary, you are free to withdraw from the study at any
time. The decision not to consent to the participation in this experimental session will
have no adverse consequences. You are free to withdraw and request that your data
be irretrievably deleted at any point up to the end of the final testing session. If you wish to opt out, please contact study researcher Paula Geiser (geiserp@tcd.ie), who will
be able to organise this for you.

What happens if I change my mind about participating?

If you choose to withdraw during the course of the experimental session, you will be
paid/offered the amount of monetary remuneration (or research credits for Psychology
students) commensurate with the total proportion of the study you have participated
in. If you decide to withdraw your consent and your data from the study immediately
after the completion of an experimental session, all of your data will be permanently
deleted. However, it will not be possible to delete your data after all experimental

sessions are completed, as all data will be irreversibly anonymised and pooled with
other participants' data at this point, so it would be impossible to identify which data
are yours.

How will the study be carried out?
The study involves completing an online survey as part of a pre-lab assessment. These data will be collected through SurveyMonkey. During the online survey, you will be asked several questions regarding your political opinion and your worldview. These data are necessary to recruit participants from different political spectrums and to later on study differences in decision-making between these groups. Data storage information surrounding data collected through the website is available before participation. The online survey must be completed before the scheduled in-person session and take about 5-7 minutes to complete. The in-person session will involve computerised tasks and anticipated to last approximately 2 hours. It is anticipated that a total of 40 participants will take part in this study.

The in-person testing session will be arranged at a time of your preference during the
week working hours (9 am – 6 pm). This session will take place in the EEG testing room located in the Lloyd Institute, Trinity College Dublin. During each testing session
you will be asked to perform a computerised task that requires simple forms of decision-making about items presented on the computer screen. In the task you will
be required to track the motion direction of a cloud of dots. While you are performing
these tasks, electrical changes in your brain will be recorded non-invasively using electroencephalography (EEG).

What will happen if I decide to take part?
If you agree to take part, the experimenter will contact you over email to arrange a suitable date for the testing session. On the day of the testing, you will be greeted at
the lobby in the Lloyd Institute (by Paula Geiser). At the beginning of the experimental session, you will be given plain information about the experimental procedure and your right to withdraw at any point. You will also be verbally informed about the policies employed so that your data remain confidential throughout the study. You will be free to ask the experimenter any questions and clarify any concerns. In the case you verbally declare that you are happy to take part in the study, you will be asked to read and sign a consent form.
Following this, equipment preparation will take place, which will take roughly 30-40 minutes. EEG simply involves applying 128 electrodes to the scalp using an EEG

cap. A small amount of conductive gel is placed in the ports on the cap and the electrodes
are clipped in to sit comfortably on top of the scalp (as shown in the picture). The gel is hypoallergenic, non-staining electrode gel. The experience is perfectly comfortable, but it does mean that you will have water soluble gel in your hair at the end of the experiment. This gel washes out easily.

During the equipment setup, you will be given detailed instructions about how to perform the computerized tasks and you will get the chance to practice before the experiment begins. You will use the keyboard to indicate your responses. After the practice trials, the main part of the experiment will take place, where you will be asked
to complete a longer version of the task that you have just practiced. This procedure
will take roughly 1 hour.

You will have the opportunity to take regular breaks during the testing session. After
the conclusion of the experimental session, you can use the dedicated hair washing
facilities of the Llyod building near the testing room where you will be offered toiletries
and a towel. Otherwise, you can wait until you return home to wash the conductive gel
from your hair.

Are there any benefits to taking part in this research?
Participating in this study will not provide direct benefits to you. However, research conducted using your EEG and task response data may enhance our understanding of the neural mechanisms underlying perceptual decision-making, particularly in relation to different political orientations. Your participation contributes to scientific advancements that may benefit future generations.

Are there any risks to me to others if I take part?
EEG is not associated with any risks for healthy adult participants. On the day of the testing session, you will undergo training blocks before the main experimental block starts and you will not continue to the main experimental blocks if you experience any kind of discomfort. Any identifying information from this study will be kept strictly confidential and will not be made available to any other people, except in circumstances that exceed the statutory limits to confidentiality. While there is no foreseeable reason for such a situation to arise in the context of this study, confidentiality may be breached if:

a) The research team has a strong belief or evidence exists that there is a serious risk of harm or danger to either the participant or another individual.

b) Disclosure is required as part of a legal process or Garda investigation. In such instances, information may be disclosed to significant others or appropriate third parties without permission being sought. Where possible, a full explanation will be given to the participant regarding the necessary procedures and the intended actions
that may need to be taken.

2. Data Protection

We aim to publish our results in scientific journals, but any published information will
be non-identifiable. Special personal data (your political opinion) and basic personal data (e.g. your age), physiological measures (EEG), measures of your behaviour on the computerized tasks, will be collected. These data will be anonymised, meaning that they are identified by a code and not including any personal information. Any basic personal information will be used solely to provide demographic information about the participants (e.g. the average age of a participant) and to rule out the possibility that such factors influence our observed results. No identifiable personal information will be shared with other researchers under any circumstances. Under the Freedom of Information Act you can have access to any information we store about you, if requested.

What will happen to my data?
Your personal information will be assigned a unique code number at the beginning of
the testing session. This code will be communicated to you at the beginning of the testing session. This code will subsequently be stored by the research team in a single
password-protected, encrypted Excel file. The encrypted file will be deleted on completion of the project. At this point all data will be irreversibly anonymised. Your EEG, eye-tracking, task response, neuropsychological data and questionnaire will be anonymised, encrypted, and securely stored both in a TCIN computer accessible only to the research team, and on a secure Microsoft OneDrive account accessible only to the main experimenters (Paula Geiser, Professor Redmond O'Connell and the Research Assistants). The data will be maintained by the O'Connell Lab indefinitely for the purposes of audit and reinvestigation. The data will be anonymized and by no means identifiable or accessible by individuals beyond the jurisdiction of GDPR, before being made available on online open science platforms (for example Github) for allowing the replication of the findings by reviewers and other researchers, open scientific dialogue, and planning of further research.

How will my data be secured?

Your privacy is important to us. We take many steps to make sure that we protect your
confidentiality and keep your data safe. In compliance with the 2018 Health Research
Regulations, in particular with the regulations 3(1)(a) – I, your data will be made completely anonymous before being shared to the approved researchers or to any online research platform, ensuring that no damage or distress will be caused to you
as a result of the processing of your personal data. Furthermore, your consent form
will be stored in a locked cabinet to which only the research team will have access. Your identity will not be revealed in any scientific meetings or through any other means
of public, scientific communication. Your data will be treated in full compliance with the
General Data Protection Regulation (GDPR) and Freedom of Information Act. Trinity
College Dublin has appointed a Data Protection Officer and their contact details can
be found on the last page.

What is the legal basis of the use of my data?

[1] [2] By law, we can use your personal information for scientific research (in the public [3] interest. We will also ask for your explicit consent to use your data as a requirement
of the Irish Health Research Regulations. You are entitled to:

- The right to access to your data and receive a copy of it
- The right to restrict or object to processing of your data
- The right to object to any further processing of the information we hold about you
- (except where it is de-identified)
- The right to have inaccurate information about you corrected or deleted
- The right to receive your data in a portable format and to have it transferred to
- another data controller
- The right to request deletion of your data

By law you can exercise the following rights in relation to your personal data. You can
exercise these rights by contacting Trinity College Data Protection Officer (all contact details can be found on last page). Note, however, that retrieval and/or

deletion of your data will not be possible once data collection for the study has finished and data are irreversibly anonymised. For this reason, if you wish to access your data or for it to be deleted, you must indicate this before completion of the project.

3. Costs, Funding, and Approval

Has the study been approved by the Research Ethics Committee?
Yes, this study has been approved by the School of Psychology Trinity College Dublin Research Ethics Committee.

Will I be paid for taking part?
If you are a TCD Psychology student, you will be given one research credit per half
hour of participation as part of the School's Research Credit Scheme or offered €10
per hour of participation. If you are not a TCD Psychology student, you will be offered
€10 per hour, as compensation for your time and travel expenses. No expenses are
required on your part if you agree to take part.

4. Further Information

Who should I contact if I have a question or complaint?
If you have any further concerns or questions about this stud, please do not hesitate
to contact a member of the research team or the Data Protection Officer. Additionally, under GDPR, if you are not satisfied with how your data are being processed, you have the right to lodge a complaint with the Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2, Ireland.
Website: www.dataprotection.ie

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Data Controllers
Trinity College Dublin

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[1] The European General Data Protection Regulation (GDPR)

[2] Article 9(2)(j)

[3] Article 6(1)(e)

Debriefing Form

TRINITY COLLEGE
Institute of Neuroscience
TCIN *from molecules to mind*

EEG study Investigating the relationship between meta-Cognition and Political Beliefs

Dear Participant,

Thank you for taking part in this study investigating how different thinking styles contribute to our political beliefs. The strategies used within the human brain during perceptual decision-making represent an important area of investigation, as it will provide insight into how perception and action operate adaptively in the human brain. EEG can be used to help us understand how people make and evaluate decisions.

The focus of this study is to see how the brain manages decision making differently and similar across different political belief systems.

The data we collect from our participants will be pooled and statistically analysed in order to gain a more thorough understanding of how decision-making is carried out in the human brain. If you have any questions about the study, please contact a member of the research team.

The terms of use of your data are outlined in the EU General Data Protection Regulation (GDPR). We would like to remind you that your data will remain confidential at all times. Following this session, your data will be irreversibly anonymised and pooled with all other participants data before being analysed. This pooled, anonymised data will be kept indefinitely to facilitate future audits or reinvestigation. In addition, this anonymous data will be shared on an online open science platform to allow for replications of the findings by reviewers and other researchers, open scientific dialogue, and planning of further research. Any basic personal information you provided will be used only to provide aggregated demographic information about the study's sample (e.g. average age). No individual personal information will be shared under any circumstances.

If you have experienced any distress as a result of taking part in this study, contact details for the Trinity College Counselling Service and the Samaritans are provided below.

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Support Services:

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