**Neuroanatomical Correlates of System-justifying Ideologies: A Pre-registered Voxel-based Morphometry Study on Right-Wing Authoritarianism and Social Dominance Orientation**

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**Abstract**

System-justifying ideologies are a cluster of ideals that perpetuate a hierarchical social system despite being fraught with inequalities. Right Wing Authoritarianism (RWA) and Social Dominance Orientation (SDO) are two ideologies that have received much attention in the literature separately and together. Given that these ideologies are considered to be stable individual differences that are likely to have an evolutionary basis, there has yet to be any examination for volumetric brain structures associated with these variables. Here, we propose an investigation of overlapping and non-overlapping brain regions associated with RWA and SDO in a sample recruited in Singapore. Indeed, it will be interesting to determine how RWA and SDO correlate in a country that proactively promotes institutionalised multiculturalism such as Singapore. In this registered report, we intend to perform a correlational test between RWA and SDO, and an a priori Voxel-Based Morphometry (VBM) analysis to determine the neuroanatomical correlates of RWA and SDO. This study advances four central hypotheses: (a) RWA and SDO will be strongly correlated despite the low ideological contrast in Singapore’s sociopolitical system (b) volume of the amygdala will be positively associated with both RWA and SDO scores, (c) ventromedial prefrontal cortex (vmPFC) volume will be negatively associated with RWA and (d) insula volume will be negatively associated with SDO. The analysis plan and VBM preprocessing pipeline will be made available online on the OSF. Ultimately, we aim to corroborate the claim of RWA and SDO as stable individual differences by establishing their relation to specific structural areas of the brain.

**Keywords**: System-justifying ideologies; Right-wing Authoritarianism; Social Dominance Orientation; Voxel-based Morphometry; Gray Matter Volume

**1. Introduction**

*1.1. Background*

Altemeyer (1998) conceptualised right wing authoritarianism (RWA) as an ideology that can be understood as a cluster of three covarying traits: authoritarian submission, authoritarian aggression and conventionalism. That is, these traits comprise a singular measure of RWA. Authoritarian submission or the tendency to almost unquestioningly obey an authority figure is one such hallmark trait of RWA. The field of social psychology has also empirically investigated this notion of obedience to authority through controlled manipulations in the lab. Arguably, no one is more influential in this regard than Stanley Milgram and his obedience experiments. In these seminal studies, Milgram (1963, 1974) found that more than half of his ‘teacher’ participants were willing to deliver (allegedly) fatal electric shocks of 450V to a ‘learner’ (a research confederate) on the other side of the room with nothing more than a reassuring you-will-not-be-held-responsible statement by a man in a white coat. These were certainly not demented nor sadistic individuals who participated. They were average university students and adults from the community (Milgram, 1974). It is often interpreted from these experiments that the influence of an authority figure is strong enough for individuals to forego their principles to follow instructions regardless of the harm they may inflict on another. In fact, these findings have been extended to other countries beyond the Americas, such as Jordan (Shanab & Yahya, 1978) and Australia (Kilham & Mann, 1974) indicating that this finding is not culture specific (see Blass, 1999 for review). Nonetheless, one can easily dismiss this as a peculiarity of that period of time. Maybe people were just more ‘authoritarian’ then. On the contrary, nearly half a century after the first series of Milgram’s experiments, Burger (2009) replicated – albeit not completely given the ethical issues rife in the original study – the same obedience task and drew the conclusion that typical individuals respond to authority much the same way now as they did 45 years ago. The replication of these findings across generations suggests that authoritarian submission, and by extension the RWA ideology or “follower’s authoritarianism”, may have a strong biological component (see Warner et al., 2016). A similar case can be made with a related ideology known as social dominance orientation (SDO), which has conversely been referred to as “leader’s authoritarianism” (Kleppestø et al., 2020). We propose that the biological component of RWA and SDO may manifest as neural structures that differ across individuals. Therefore, in this report, we aim to use voxel-based morphometry (VBM) to identify the neuroanatomical correlates that vary as a function of self-report scores in RWA and SDO scales.

*1.2. System-Justifying Ideologies*

Around the globe, the majority of modern societies are grounded on a hierarchical social system with a substantial proportion of its members found to be tolerant, or sometimes accepting, of the structural inequalities that come about as a result of the hierarchy (Jost et al., 2004; Marshall, 2000; Muller, 2001; O’Higgins et al., 1990). Notably, there is an uneven distribution of resources among its members, whereby some have more than others – often substantially more – yet people still believe that these are distributed fairly. Inherent in such hierarchies are inequalities in the treatment of its members by virtue of race, gender, political orientation and other traits that may characterise such individuals as the ‘outgroup’ (Abrams et al., 2014; Hamley et al., 2020; Hornsey et al., 2003). Despite this recognisable unequal treatment, society members, particularly those at the bottom of the hierarchy (Jost et al., 2003; van der Toorn et al., 2015), have a general tendency to legitimise and accept the status quo (Baryla et al., 2015; Jost & Banaji, 1994; Jost et al., 2004).

Jost & Hunyady (2005) argue that individuals adopt different system-justifying ideologies as a means to maintain the status quo. These include, but are not limited to, meritocratic ideology, political conservatism, belief in a just world, RWA and SDO. These ideologies serve the same purpose of rationalising and legitimising social inequalities but the observable manifestations of each ideology may differ. Among many others, the two latter are prominent ideologies that are worth highlighting: RWA and SDO. We examine these two specifically for three reasons. First, there is a substantial amount of existing research on these two ideologies, both separately and simultaneously (Duckitt & Sibley, 2009; Mirisola et al., 2007; Roccato & Ricolfi, 2005; Ruffman et al., 2019). Second, RWA and SDO, when pitted against other relevant predictors, have been shown to account for the vast majority of variance in intergroup attitudes and behaviours important in perpetuating a hierarchical social system, such as prejudice (RWA: Altemeyer, 1998; Roets et al., 2015; Wylie & Forest, 1992; SDO: Pratto et al., 1994, 2006; RWA & SDO: Asbrock et al., 2010; Duckitt & Sibley, 2007, 2010; Duriez & Soenens, 2009; Whitley, 1999). Third, past cross-cultural research documents a correlated but independent relationship between RWA and SDO (Duckitt & Sibley, 2009; Roccato & Ricolfi, 2005), which presents a reasonably robust foundation for examination beyond analysis of explicit evaluations (i.e. self-report). Before going further, we first need to expound on these two measures.

*1.3. Right Wing Authoritarianism*

RWA is indexed as a self-report score based on a 32-item questionnaire constructed by Altemeyer (1981, 1996, 1998) to measure the covariation in an individual’s 1) submission to authority (i.e. authoritarian submission), 2) aggression against those who deviate from the norm (i.e. authoritarian aggression) and 3) preservation of traditions, typically those advocated by authority figures (i.e. conventionalism). Each item is rated on a 9-point Likert scale indicating the individual’s agreement with each statement from -4 (very strongly disagree) to +4 (very strongly agree). Although recent research argues that dividing RWA into its subcomponents can add greater nuance and better explanatory power to intergroup outcomes (e.g. Authoritarianism-Submission-Traditionalism scale, Mallinas et al., 2020; “authoritarian aggression and submission’’ and ‘‘conservatism’’ dimensions, Rattazzi et al., 2007), past findings involving correlations with the superordinate RWA measure supports the notion that this singular measure is likely to be more than sufficient in capturing the large majority of variance in the data (Altemeyer, 1998; Claessens et al., 2020; Duckitt & Sibley, 2009).

*1.4. Social Dominance Orientation*

SDO is also measured using a self-report score based on a 16-item questionnaire (Pratto et al., 1994). Each item is rated on a 7-point Likert scale indicating the individual’s agreement with each statement from 1 (strongly disagree) to 7 (strongly agree). Pratto et al. (1994) define SDO as “the extent to which one desires that one's in-group dominate and be superior to out-group”. One of the most notable ways by which individuals justify inequalities in society is by legitimising the discrimination in the existing hierarchy as indisputable facts (Sidanius, 1993). Following this reasoning, the social dominance model predicts those higher in SDO scores are more likely to endorse these hierarchy-legitimising beliefs and the policies that maintain these beliefs. Indeed, this conjecture has been examined and verified in various extensions of the original study (Pratto et al., 1994; e.g. Aiello et al., 2017; Caricati, 2007).

*1.5. Right Wing Authoritarianism and Social Dominance Orientation as Separate Constructs*

RWA and SDO represent relatively stable and longstanding individual differences. In other words, people vary in their levels of RWA and SDO. These differences tend to decrease with age but show reasonable consistency in adult samples (Ruffman et al., 2020). Despite being measured as separate scales in most research, some have raised the possibility that the correlation between RWA and SDO might denote that they can be subsumed to a unidimensional spectrum (Jost et al., 2003a, 2003b; for opposing views, see Greenberg & Jonas, 2003; Duckitt & Sibley, 2007). Conceptually, this makes sense given that both RWA and SDO are system-justifying ideologies that strive to directly influence the stability of the social hierarchy (e.g. through promoting prejudice attitudes and behaviour towards low-ranking members to keep them at the bottom), as opposed to others such as, Protestant work ethic and meritocracy that do so indirectly (e.g. espouses the idea of those who are at the bottom to have deserved their situation; Jost & Hunyady, 2005). Moreover, their authoritarian nature – both measures deal with either submitting or subjecting others to authority and thus maintaining a hierarchical social structure – can lead one to suspect that RWA and SDO exist along a single ideological dimension.

Nonetheless, there is much more evidence to indicate that these measures reflect independent constructs. Roccato and Ricolfi (2005) conducted a cross-cultural meta-analysis to show that the correlation between the two measures is contingent on the ideological contrast of the country by which the population was studied. For instance, Italy has a distinctively left-right political environment, in which case RWA and SDO are likely to covary due to the more structured and rigid political attitudes and behaviours anchored along the left-right dimension. Individuals who are leftist (i.e. liberal) were likely to score low on both RWA and SDO whereas rightist individuals (i.e. conservative) scored high on both RWA and SDO, particularly among those with a strong identification with their political orientation (Mirisola et al., 2007). Conversely, countries with minor ideological contrast, that is, political attitudes and behaviours do not align very neatly along a left-right dimension, reported RWA and SDO independent of each other. Indeed, one study in a Canadian sample (a country low in ideological contrast) report one of the lowest correlations between RWA and SDO (e.g. *r* = .08; Altemeyer, 1998). A similar case can be said about the phenomenon that both RWA and SDO reliably and, in most cases, in the same direction, predict prejudice. The dual process model (DPM) by Duckitt (2001) asserts that, although the attitudinal and behavioural outcomes are visibly similar, the underlying beliefs for prejudice in high SDO and RWA individuals are different. According to the model, prejudice attitudes and behaviour in high RWA individuals are motivated by threats to one’s security and unpredictability whereas high SDO individuals are motivated by superiority and competitiveness (Asbrock et al., 2010; Claessens et al., 2020; Duckitt, 2006; Duckitt & Sibley, 2007, 2009; Shaffer & Duckitt, 2013; Sibley et al., 2007; Whitley, 1999). The DPM model also accounts for the systematic cross-cultural variations by the degree of ideological contrast in each country (Roccato & Ricolfi, 2005).

However, a study by Roets et al. (2015) in Singapore represents a unique instance where higher RWA does not predict greater prejudice. Individuals who reported higher RWA scores also reported more positive attitudes towards outgroup individuals, contrary to the predicted direction by the DPM. It is worth noting that this relationship was mediated by the individuals’ perception of the government’s stance on multiculturalism in Singapore. To elaborate, the Singapore government enacts measures to promote intergroup contact and interaction among its citizens, such as through ethnic quotas in public residential buildings and schools (Noor & Leong, 2013). The top-down influence of the government has, in this case, reversed the typically positive correlation between RWA and prejudice. To reiterate, the correlation of RWA and SDO is largely a function of the ideological contrast of the national context it is embedded in (Rocatto & Ricolfi, 2005). Specifically, countries that have a strong ideological contrast tend to promote a political left-right dimension such that individuals that ascribe to a specific political ideology (i.e. left vs right) tend to show positively correlated RWA and SDO scores. More relevant to this paper, the sociopolitical context of Singapore does not feature an explicit left-right dimensionality and so, would be considered a country of low ideological contrast. Therefore, the DPM model would predict that RWA and SDO would be largely independent of each other in the Singapore context. However, the DPM does not make clear predictions with regards to institutionalised processes (i.e. governmental promotion of multiculturalism) that may influence system-justifying ideologies (see Guimond et al., 2014). To the best of our knowledge, no study has yet been done to investigate the correlation between RWA and SDO in Singapore. Though the influence of multiculturalism policy on SDO have not yet been measured in Singapore, research in other countries that show a negative correlation between support for multiculturalism and SDO indicates a trend towards that direction (e.g. France: Kamiejski et al., 2012; USA: Levin et al., 2012). In fact, the study conducted by Levin and colleagues (2012) demonstrated multiculturalism as a strong mediating factor for the relationship between SDO and prejudice towards minority groups. Therefore, based on the large role multiculturalism plays in Singapore’s sociopolitical environment, there is good reason to believe that RWA and SDO will be influenced similarly, thus boosting the correlation between these two ideologies (H1). Notably, this would be in stark contrast to other industrialised and low ideologised nations identified in the meta-analysis by Roccato and Ricolfi (2005) that feature weak correlational measures of RWA and SDO.

*1.6. Neural Correlates of Right Wing Authoritarianism and Social Dominance Orientation*

This paper aims to determine the neuroanatomical correlates of RWA and SDO. In particular, we aim to distinguish the overlapping and non-overlapping brain regions associated with scores in the RWA and SDO scales using a VBM technique. Although traditional self-report measurements of RWA and SDO have demonstrated robust reliability and validity across multiple studies, the examination into the neural bases of RWA and SDO can provide more solid evidence for their status as stable individual differences. Recently, there have been some efforts towards this direction. For instance, the DPM of threat and competition has been shown to map well with the two-dimensional evolutionary framework of economic conservatism (i.e. dominance) and social conservatism (i.e. authoritarianism) such that RWA and SDO are likely to have been adaptive and have, over evolutionary time, developed a heritable biological basis (Claessens et al., 2020). This evolutionary framework can help navigate the possible neural substrates of RWA and SDO, and in particular, where these two system-justifying ideologies intersect in the brain (i.e. overlapping brain regions). We also predict that these overlapping and non-overlapping brain regions correspond to the tenets of DPM. We predict that RWA and SDO would involve identical brain regions as they are both system-justifying ideologies that individuals espouse to maintain the hierarchical structure of society. Additionally, these constructs correlate but are nonetheless independent, and would therefore recruit unique brain regions to differentially substantiate these ideologies in terms of antecedents and outcomes as propounded by the DPM model.

Granted the conceptual overlap and correlation in RWA and SDO, we have reasonable confidence that these two ideologies are likely to covary with, at least, one identical brain region. The amygdala is a potential candidate as an overlapping neuroanatomical correlate (see Jost et al., 2018). This subcortical region has been demonstrated to be involved in a wide range of psychological processes, such as, outgroup discrimination (Phelps et al., 2000), political inclinations (Gozzi et al., 2010; Kanai et al., 2011), and even social network size (Bickart et al., 2011). Though seemingly disparate constructs, these processes interact as socially relevant facets of any large society (Zingher, 2021), and the evidence surmounting the recurring relevance of the amygdala suggests an overarching social process governed by this region. In fact, research in how amygdala volume correlates with scores in the system justification scale points to its important role in the maintenance of hierarchical social systems (Nam et al., 2017). Therefore, both RWA and SDO, as system-justifying ideologies, are also associated with perpetuating societal hierarchies (Jost & Hunyady, 2005) and hence, the scores in these measures will presumably also correlate positively with amygdala volume (H2).

In terms of non-overlapping regions, the neurological research in RWA and SDO utilise different paradigms. One line of work in the neural substrate of RWA lies in neuropsychological research (Asp, Ramachandran & Tranel, 2012; Warner et al., 2016). Asp, Ramachandran and Tranel (2012) have shown that the ablation of the ventromedial prefrontal cortex (vmPFC) lead to greater endorsement of RWA. This association of RWA with the vmPFC lines neatly with the False Tagging Theory (FTT) that posits that the vmPFC is involved in assessing the veracity of a belief (Asp & Tranel, 2013). In other words, the vmPFC underpins the ability to doubt a belief. Predictably, individuals with damage to their vmPFC are more likely to subscribe to fundamentalist beliefs because of this ‘doubt deficit’. Similarly, Individuals with high RWA are also likely to rely on authority to dictate their beliefs and are often rigid and immutable to evidence (Altemeyer, 1998; Mirels & Dean, 2006). In line with these associations, damage to the vmPFC would lead to increased RWA scores, which was supported by their findings (Asp, Ramachandran & Tranel, 2012). The authors of the study also went to further explicate the distinction between religious fundamentalism and RWA, which can be easily conflated due to the nature of large roles of religious authority figures in promoting RWA (Whitley, 1999; Wylie & Forest, 1992). Importantly, after partialling out religious fundamentalism, Asp, Ramachandran & Tranel (2012) found that the degree of vmPFC damage still led to higher RWA scores, suggesting that the fundamentalist beliefs associated with RWA is not exclusive to a religious context (Krauss, Streib, Keller & Silver, 2006). ​​In other studies, vmPFC lesions are also implicated in changes in performances of tasks related to the covariations of RWA, such as authoritarian submission (e.g. tests of belief; Asp, Manzel, et al., 2012), and conventionalism (e.g. gender stereotyping; Milne & Grafman, 2001) further corroborating the role of vmPFC in RWA. These findings implicating vmPFC damage to increase in self-report RWA and changes in its covariations suggests that this brain region may have a volumetric relation with individual difference in RWA. That is, we hypothesise that variation in RWA scores will be negatively associated with the structural volume of vmPFC (H3).

In terms of SDO, although no current work has been done to directly examine its neuroanatomical correlates, research in functional brain imaging suggests some possible areas of interest (Cazzato et al., 2015; Chiao et al., 2009; Ligneul et al., 2017). It is important to highlight that these functional scans reveal varying activated brain areas. These variations in brain areas are potentially attributable to the different tasks employed in each study. Chiao et al. (2009) measured empathic response to stimuli involving pain (and no pain) and found higher SDO scores covaried with reduced activation in the anterior cingulate cortex (ACC) and insula when perceiving pain in others. To rule out alternative explanations, the authors also conducted a thorough manipulation check on whether the participants think that the individual in the image is experiencing pain. By contrast, a more recent study found that SDO was associated with activity in the dorsolateral prefrontal cortex (dlPFC) and superior temporal sulcus (STS) when viewing faces associated with different social ranks (Ligneul et al., 2017). The latter study, however, defined “social ranks” based on rate of winning in the task, operating under the presumption that those who win more than the participant are seen as “superior” and those who lose more as “inferior”. It is possible that participants did not perceive any social ranking during the task at all. As there was no manipulation check for this implicit assumption, it is not clear why SDO scores covaried with dlPFC and STS activity. Consequently, the association between SDO and dlPFC and STS regions may not be borne out once this particular task is no longer carried out during the brain scan. The methodology in the study by Chiao et al. more conceptually aligns with the construct of social dominance measured by the SDO scale because it involves empathic concern, a process that has an important relationship with social dominance (Sidanius et al., 2013). Another study involving the role of SDO in moderating the performance of individuals in a gaze-following task using left- and right-wing politicians images as stimuli implicated the midcingulate cortex and insula, among other related regions – increased SDO was negatively associated with activation in these regions (Cazzato et al., 2015). Both studies suggest that there is at least one brain area that is reliably associated with SDO and that it is not simply a consequence of utilising a peculiar task. Therefore, we believe it’s likely that variation in SDO scores will be negatively associated with structural volume of the insula (H4).

Our prediction of non-overlapping neuroanatomical regions associated with RWA and SDO suggests an independence of function between these two ideologies at the neural level. Though there is no direct evidence for this double dissociation, some indirect evidence in the literature hints to this possibility. The study by Asp, Ramachandran & Tranel (2012) demonstrated that only damage to vmFPC was significantly associated with higher RWA scores compared to healthy controls. Patients with damage to other neural structures, including those that are involved with emotion, did not show this increase in RWA scores. The etiologies of these non-vmPFC lesions were not overly specified. Notwithstanding, this distinctiveness of RWA scores associated with only vmPFC damage and not other cortical regions implicated in emotional processing leads us to hypothesise that RWA is likely not to associate with the insula. Importantly, this non-vmPFC lesion group excludes patients with specific damage to the amygdala. Thus, the predicted overlapping association of RWA and SDO with the amygdala remains intact. Moreover, only Chiao et al. (2009) has thus far conducted a whole-brain analysis to identify regions that covary with SDO scores during an fMRI task. SDO scores were a significant predictor of frontal areas, namely, inferior, superior and middle frontal gyri activity, in addition to the aforementioned ACC and insula activity when participants engaged in an empathic task. However, after controlling for age and self-reported dispositional empathy, only the ACC and insula were left as regions significantly associated with SDO scores. To our knowledge, no other studies have conducted a whole-brain analysis involving SDO. Comparing with the study by Cazzato et al. (2016), only the insula region consistently covaries with SDO scores across different fMRI tasks. Based on the limited research on this topic, we hypothesise that SDO but not RWA will be associated with the insula and RWA but not SDO will be associated with vmPFC.

*1.7. Present Study*

Both RWA and SDO has been shown to exhibit cross-cultural validity (Roccato & Ricolfi, 2005), temporal stability (Osborne et al., 2017; Ruffman et al., 2019), and association with brain lesion (RWA: Asp, Ramachandran & Tranel, 2012;) and brain activity (SDO: Cazzato et al., 2015; Chiao et al., 2009). The neurological research on authoritarian-related and dominance-related ideologies has laid the groundwork on potential neuroanatomical correlates of SDO and RWA and their possible overlaps. Moreover, the evolutionary framework provides evidence for the adaptive potential of a biological basis for RWA and SDO. Therefore, it is reasonable to suspect that the individual difference in scores for these measures would covary with neuroanatomical differences (see Kanai & Rees, 2011). Yet, these neuroanatomical correlates have not been examined. In addition, we will also assess the relationship between RWA and SDO in the Singapore population. It is worth noting that the sample represented in this study is only of the majority Chinese ethnic group. In a review of the influence of policies on intergroup relations, Guimond et al. (2014) assert that the impacts of intergroup-related policies, such as multiculturalism policies, vary to the extent such that cultural perceptions of majority group individuals towards such policies may not represent those of minority group individuals. Therefore, findings in this paper may not extrapolate to the entire Singapore population and may be restricted to those of the ethnic majority group. Nonetheless, the study still holds merit in that limiting the study to only the majority ethnic group can allow the focus on a relatively homogenous sample to maximise statistical power. Future studies that examine neuroanatomical correlates of RWA and SDO scores should subsequently include ethnic minority groups to examine possible differences in their neuroanatomical correlates of RWA and SDO. Notwithstanding, we put forward the following specific hypotheses we aim to address: (a) H1: RWA and SDO will be strongly correlated despite the low ideological contrast in Singapore’s sociopolitical system, (b) H2: volume of the amygdala will be positively associated with both RWA and SDO scores, (c) H3: vmPFC volume will be negatively associated with only RWA and (d) H4: insula volume will be negatively associated with only SDO. To verify these predictions, we will conduct a correlational test for (a) and VBM analyses to estimate gray matter volume in these brain regions for (b) - (d).

In this proposed study, we will be conducting secondary analysis of structural MRI data of participants that were recruited for an fMRI study. To do so, we will be focusing on the structural MRI images that were used as an anatomical reference for that study. Responses to RWA and SDO scales were also collected from these participants but these have not been analysed thus far. Taken together, the proposed statistical analyses will primarily consist of a correlational test between RWA and SDO scales, and VBM analyses (Ashburner & Friston, 2000) of prespecified brain regions implicated in RWA, SDO or both. We opted for a region of analysis (ROI) approach to strengthen the power to detect true effects in our study (Cremers et al., 2017). The ROIs identified in our analyses are primarily derived from the regions specified in hypotheses (b) - (d), which were in turn informed by our review of the existing literature. In addition to the ROI analyses, a whole-brain analysis will also be conducted.

**2. Methods and materials**

*2.1. Overview*

The self-report and structural MRI data collection has already concluded. However, the raw self-report data have not been analysed prior to this proposal. In this study, we aim to analyse the RWA and SDO data and test our hypotheses by conducting a combined region of interest (ROI) and whole-brain VBM analysis. Additionally, we will test the correlation in self-report scores of RWA and SDO scales.

*2.2. Participants*

Ninety-one (46 females) participants were recruited for this study (age range is 21 to 41 years old). All participants were Singaporean Chinese students recruited from Nanyang Technological University (NTU) or Singaporean Chinese adults from the local community, respectively. Each participant was required to provide written informed consent before participating in the study in accordance to the Declaration of Helsinki. This study was approved by the NTU IRB (Protocol 2017-01-029).

There were two phases of recruitment in the study. The inclusion criteria of both phases are as follows: (a) Chinese Ethnicity (b) English-speaking, (c) right-handed, (d) possess normal or corrected-to-normal vision and hearing, (e) no diagnosis of intellectual disabilities (f) no psychiatric/neurological illness and (g) no history of illicit drug use. Eligible participants were instructed not to consume any caffeine or medication 24 hours prior to their scan. We excluded Chinese Singaporean participants who travelled overseas for more than two months over the past six months from the time of the scan session. In addition, with particular focus on the safety of the participants, individuals with claustrophobia, any metallic prosthesis, and/or copper intrauterine devices, were not eligible for the MRI section of the study. Finally, female participants at any stage of pregnancy were not eligible for the study. The first recruitment collected data from N = 56 (27 females; mean age 23.05 ± 1.31 years).

The second recruitment phase had identical inclusion and exclusion criteria as the first phase. The main difference is that for this phase, the target sample was middle-aged adults from the community. The second recruitment collected data from N = 35 (19 females; mean age 31.59 ± 6.59 years).

In total, 91 participants were recruited to participate in this study. Nine participants were excluded from the main analysis because of incomplete MRI or self-report data. Therefore, the final sample is N = 82 (43 females; mean age 25.89 ± 5.68 years).

*2.3. Materials*

*2.3.1. RWA scale*

The Right-Wight Authoritarianism Scale (RWA; Altemeyer, 1981) is a 32-item self-report scale that measures authoritarianism. The RWA scale has been shown to demonstrate high degrees of reliability and validity (Altemeyer, 1981, 1996; Christie, 1991). The RWA scale in this study used a 22-item version (Altemeyer et al., 2006; Appendix A). The 22-item scale is used in this study as it is the most updated version of the RWA scale and demonstrates comparable psychometric properties as the original 32-item scale. Therefore, we opted for this shortened version of the scale. Participants responded to them on a 9-point Likert scale with anchors at each point. The responses ranged from -4 (very strongly disagree) through 0 (neutral) to +4 (very strongly agree). The scale used in this study sampled statements that represent the three covariations in the original 32-item RWA scale, such as, “ The established authorities generally turn out to be right about things, while the radicals and protestors are usually just “loud mouths” showing off their ignorance” reflecting authoritarian submission trait, “Our country will be destroyed someday if we do not smash the perversions eating away at our moral fiber and traditional beliefs” reflecting the authoritarian aggression trait, and “The “old-fashioned ways” and “old-fashioned values” still show the best way to live” reflecting the conventionalism trait. Though they reflect arguably independent subscales (Mallinas et al., 2020; Rattazzi et al., 2007), the consensus in the literature indicates that total RWA score is sensitive enough to detect variation in authoritarian-related individual differences (e.g. Altemeyer, 1998; Duckitt & Sibley, 2009; Ruffman et al., 2019). Moreover, dividing either SDO or RWA into their respective subcomponents add greater complexity and better explanatory power to expected psychological and neurological outcomes but the correlations between SDO and RWA in past research supports the notion that they are more than likely to be sufficient in capturing the already greater majority of variance in the data (Claessens et al., 2020). Therefore, a single RWA score was obtained by summing the responses to each item, after reverse-coding the anti-authoritarian items.

*2.3.2. SDO scale*

The Social Dominance Orientation (SDO; Pratto et al., 1994) is a 16-item self-report scale that measures social dominance. The SDO scale has been shown to demonstrate high degrees of reliability and validity (Pratto et al., 1994). The SDO scale in this study used the original 16-item version (Appendix B). Participants responded to them on a 7-point Likert scale with anchors at each extreme. The response ranged from 1 (strongly disagree) to 7 (strongly agree). Examples of these statements include, “Some groups of people are simply inferior to other groups,” “In getting what you want, it is sometimes necessary to use force against other groups,” “It's OK if some groups have more of a chance in life than others”. A single SDO score was obtained by summing the responses to each item, after reverse-coding the anti-dominance items.

*2.4. Self-Report Data Analysis*

Prior to running inferential statistical analysis, RWA and SDO scores will undergo preliminary analysis to check that assumptions for parametric testing are fulfilled. In particular, the normality of responses for each item will be verified using skewness and kurtosis recommended cut-off of +/- 3 values. Items that do not fulfil the normality assumption will be removed from further analysis. To assess the inter-item reliability of the RWA and SDO scale, a Cronbach’s alpha will be calculated for each scale. The correlation between RWA and SDO will be measured using a test of Pearson’s correlation. Both statistical tests will be performed using SPSS 26.0 (SPSS Inc., Chicago, IL).

*2.5. Power Analysis*

In this study, we will conduct a set of ROI-analyses based on prespecified brain regions shown to have associations with RWA, SDO or both. Because there has yet to be any published work measuring the neuroanatomical correlates of RWA and SDO in the extant literature, we are unable to make specific estimates for the effect size. Hence, we decided upon a medium effect size of *f* = .15 for our analysis. To achieve at least a power value of .80 at an alpha level of *p* < .05, a sample size of N = 55 is needed. In addition, the test of correlation between RWA and SDO requires a sample size of N = 67 to achieve a power of 0.8 at p < .05. Our study exceeds both criteria with a final sample size of N = 82, and consequently, we believe this to be a well-powered sample to provide an accurate estimate of the effect size regarding system-justifying ideologies and their respective structural brain associations.

*2.6. MRI Acquisition*

All MRI data was collected using a Siemens Magnetom Prisma 3-Tesla MRI Scanner with 64-channel head coil. High-resolution T1-weighted MPRAGE sequences (192 slices; TR 2300ms; TI 900ms; flip angle 8 degrees; voxel size 1mm) were obtained to serve as neuroanatomical raw data. Each participant was fixed to an external head restraint to minimize head movement during the scan.

*2.7. VBM Preprocessing*

Processing of the structural data will be performed using Statistical Parametric Mapping (SPM12; Wellcome Department of Imaging Neuroscience, <http://www.fil.ion.ucl.ac.uk/spm/software/spm12>) on Matlab 2021a platform. First, T1-weighted images will be segmented using the diffeomorphic anatomical registration through exponentiated lie algebra (DARTEL) for intersubject registration into grey matter probability maps. Images are to be spatially normalised with modulation to preserve the total amount of gray matter, then transformed into the Montreal Neurological Institute (MNI) stereotactic space to produce 1 x 1 x 1 mm3 voxels. Finally, they will be smoothed by convolving the images with an isotropic Gaussian kernel of 12 mm full width at half maximum (FWHM; Ashburner & Friston, 2005; Kanai, et al., 2011; Nam et al., 2018).

*2.8. ROI Analysis*

The ROI analyses will focus on these predictions: the gray matter volume of the amygdala will be positively associated with both RWA and SDO scores (H2), gray matter volume of the vmPFC will be negatively associated with only RWA (H3) and gray matter volume of the insula will be negatively associated with only SDO (H4). Specifically, our main independent variables of interest are the two measures of system-justifying ideologies (i.e. RWA and SDO scores). These regions were selected based on previous research implicating these respective regions to RWA, SDO or both. With respect to the amygdala, this is the only hypothesis that is based on a previously conducted neuroanatomical study (Nam et al., 2017). However, we would like to reiterate that neither the RWA nor SDO scales were analysed in the full sample of the study. Instead, a general system justification scale was used (Kay & Jost, 2003). These items tap on similar beliefs consistent with high RWA (e.g. “In general, you find society to be fair”) or SDO (e.g. “Society is set up so that people usually get what they deserve”). It is worth noting that Nam et al. (2017) previously did not find a significant correlation between SDO and amygdala volume. However, the absence of a relationship may likely have been due to the relatively small sample size (N = 37) used to analyse this relationship. Equipped with a more well-powered sample, our study (N = 82) presents a more definitive measure of a neuroanatomical correlate not only of SDO but also RWA. Therefore, we reasoned that RWA and SDO are likely to also correlate with amygdala volume (H2), as does the general system justification scale in the study by Nam et al. The link between vmPFC and RWA is also unique among the three hypotheses in that it is the only one based on a set of neuropsychological studies involving neurology patients with a lesion in this brain region (Asp, Manzel, et al., 2012; Asp, Ramachandra & Tranel, 2012; Asp & Tranel, 2013). This points to a specific role of the vmPFC in modulating RWA ideologies, such that damage to this region leads to a manifested change in both RWA scores and outcomes related to RWA such as increased religious fundamentalism (Asp, Ramachandran & Tranel, 2012) and more generally, a magnified susceptibility to misleading information (Asp, Manzel, et al., 2012). We believe it is not that farfetched to suspect that the regional volume in vmPFC correlates with the degree of ascription to RWA (H3). Finally, the insula was identified primarily from an fMRI study by Chiao et al. (2009) that found this regions to correlate significantly with SDO scores during a pain perception task. This same region was detected in another study using a different task so we can be confident that these correlations are not simply an idiosyncrasy of a specific task type (Cazzato et al., 2015). However, it is worth mentioning that the insula was implicated in this latter study as part of the ‘social orienting circuit’ in the brain but was not reported to be directly correlated to SDO scores. Nevertheless, both studies taken at face value did use tasks that tap on the essence of SDO – that is the preference for dominance in terms of observing the pain of others (Chiao et al., 2009) or perceived similarity in others (Cazzato et al., 2015). Therefore, based on the limited literature on this topic, we argue that there is value in the present structural ROI-based analysis and we do expect SDO scores to correlate with both regional volumes of ACC and insula (H4).

We intend to measure the mean grey matter volume (GMV). For each participant, we will average voxel-wise GMV values for each ROI individually, which then serves as the dependent variable for our main analyses.

We will investigate the association between GMV and scores in the RWA and SDO scales using ROI multiple regression analyses. As the brain areas in our hypotheses are identified with a strong a priori prediction, the threshold of significance was set at p < 0.05, with small volume correction for multiple comparisons in the ROIs. To analyse these regression models, we will be using the MarsBaR toolbox (<http://marsbar.sourceforge.net/>) to anatomically define ROIs for the three pre-specified brain regions (i.e. amygdala, vmPFC and insula) according to our main hypotheses. The GMVs will be extracted from their ROIs using anatomically defined spheres with a radius of 20mm centered at (MNI: x=−36, y=−9, z=−17) for the left amygdala and at (MNI: x=27, y=12, z=−21) for the right amygdala (Nam et al., 2017). We then average the mean volumes from the left and right amygdala. The ROI of the vmPFC will be anatomically defined as a sphere with a radius of 20 mm centered at (MNI: x = 0, y = 40, z = -18; Li et al., 2017). Finally, the ROI of the insula will be anatomically defined as a sphere with a radius of 20 mm centered at (MNI: x = -45, y = 26, z = -6; Chiao et al., 2009; Cazzato et al., 2015).

In these analyses, we intend to control for total intracranial volume (TIV), age and gender by including them into the regression model as independent “nuisance” variables. TIV is an important variable to account for particularly in ROI-based volumetric measures because such subtle differences in regional brain volume may be confounded by individual differences in overall brain size (O’Brien et al., 2011). We are also controlling for age not only because TIV varies as a function of age (Bartholomeusz et al., 2002), but also because both RWA and SDO have been shown to decrease with age (Altemeyer, 1998; Ruffman et al., 2020). Accounting for age is also necessitated in this study because the analysis will include participants from two different age groups, a young adult sample and a middle-aged adult sample. We would expect both self-report and volumetric brain differences between these two age groups so including age in the regression model will minimise confounds due to age differences. Finally, past research also suggests a gender difference in self-reports of RWA and SDO. In particular, women tend to report higher RWA scores than men (Brandt & Henry, 2012) whereas men tend to report higher SDO scores than women (Pratto et al., 1994). Combined with an overall brain volume difference between men and women (Kaufmann et al., 2001; Ruigrok et al., 2014; Takahashi et al., 2011), we reckoned to control for gender would facilitate in identifying significant neuroanatomical correlates, as we predict with the age variable. We would like to emphasise that although system-justifying ideologies and regional (and overall) brain volume do seem to vary with age and gender, these are treated as nuisance variables in the main analysis as they do not comprise the main objectives of the study.

Each ROI multiple regression analysis will use ordinary least squares models with the GMV as the dependent variable, and RWA (or SDO) score, gender, age and TIV as independent variables.

*2.9. Whole Brain Analysis*

To supplement the a priori ROI analysis, we will also be conducting an exploratory whole brain analysis using the DARTEL package in SPM12. As with the ROI analysis, RWA or SDO scores will be used as contrasts to test significance of regressions coefficients from zero value. Similarly, age, gender and TIV will be included as covariates. Significance thresholds will be set at a peak-level threshold of *p* < 0.05 with family-wise error (FWE) correction, and uncorrected voxel-wise level of *p* < 0.001.”

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| In the social and political context of Singapore, are RWA and SDO scores correlated? | **Question** |
| H1: RWA and SDO will be strongly correlated despite the low ideological contrast in Singapore’s sociopolitical system | **Hypothesis** |
| One-tailed Correlation: Bivariate normal model Alpha level, p = .05 N = 82 participants Power = 0.99 to detect medium effect size, r = .30 | **Sampling Plan** |
| Pearson’s correlation test between RWA and SDO scores | **Analysis Plan** |
| The degree of RWA and SDO correlation is fairly predictable given the tenets of the Dual Process Model. That is, because Singapore is a country that is low in ideological contrast, we would expect a low correlation between SDO and RWA. However, the DPM does not account for top-down ideological influence, such as the institutionalised multiculturalism seen in Singapore. Taken together, we expect a significant positive correlation but since this specific correlation has not been documented in Singapore in previous works, we opted for a conservative but medium effect size. | **Rationale for deciding the sensitivity of the test for confirming or disconfirming the hypothesis** |
| H1 is supported if the test reveals a statistically significant correlation between RWA and SDO.  Significantly negative correlations would disconfirm the hypothesis. | **Interpretation given different outcomes** |
| Dual Process Model; if RWA and SDO are shown not to be correlated, this would follow the expected trend as predicted by DPM where RWA and SDO will be independent of one another in countries with low ideological contrast. This would suggest that multiculturalism either does not influence RWA and SDO in the same direction or not strongly enough to exceed the significance threshold. We may then rule out the possibility of multiculturalism playing an additional role to explain cross-cultural correlation between RWA and SDO. | **Theory that could be shown wrong by the outcomes** |

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| Is/are there any region/s that are related to RWA but not SDO? | Is/are there any overlapping region/s that are related to RWA and SDO? |
| H3: vmPFC volume will be negatively associated with only RWA | H2: volume of the amygdala will be positively associated with both RWA and SDO scores |
| Linear multiple regression: Fixed model, R2 deviation from zero Alpha level, p = .05 N = 82 participants Power = 0.83 to detect medium effect size, f = .15 | Linear multiple regression: Fixed model, R2 deviation from zero Alpha level, p = .05 N = 82 participants Power = 0.83 to detect medium effect size, f = .15 |
| ROI multiple regression analysis with RWA and SDO scores as independent variables regressed on mean GMV of vmPFC. Age is included as a nuisance variable. | ROI multiple regression analysis with RWA and SDO scores as independent variables regressed on mean GMV of amygdala. Age is included as a nuisance variable. |
| We decided on a medium effect size as this study is investigating a fairly new hypothesis. To the best of our knowledge, there has been no published work investigating brain structures that involve both SDO and RWA in a single study. Granted previous work have not measured structural variation and simultaneously measured SDO scores, contributing work in brain lesion research and RWA scores point to this direction. | We decided on a medium effect size as this study is investigating a fairly new hypothesis. To the best of our knowledge, there has been no published work investigating brain structures that involve both SDO and RWA in a single study. Nonetheless, the correlation between amygdala volume and a conceptually similar scale (i.e. system justification scale) has been established in previous works. |
| H3 is supported if the test reveals RWA, but not SDO, has a statistically significant negative correlation with mean vmPFC volume.  Insignificant correlation of both RWA and SDO with vmPFC volume would disconfirm the hypothesis. Significantly positive correlation of either or both RWA and SDO with vmPFC volume would also disconfirm the hypothesis. Significantly negative correlation of SDO with vmPFC would also disconfirm the hypothesis. | H2 is supported if the test reveals both RWA and SDO have a statistically significant positive correlation with mean amygdala volume.  Insignificant correlation of either or both RWA and SDO with amygdala volume would disconfirm the hypothesis. Significantly negatively correlation of either or both RWA and SDO with amygdala volume would also disconfirm the hypothesis. |
| Dual Process Model; if vmPFC volumes are found to not correlate with RWA as predicted, similar interpretations can be made as with H2 (i.e. other brain regions governing RWA or vmPFC volume simply does not covary with RWA self-report scores); if vmPFC volume correlate with SDO but not RWA, this may suggest external factors may need to be accounted for in the DPM model, particularly, those that are pertinent to Singapore’s social and political context that may influence how RWA and SDO manifest. | System-justification theory; if amygdala volume is not found to overlap with individual variation in RWA and SDO, there are at least two ways of interpreting this. One, there may be other regions that govern system-justifying ideologies in general. Two, individual variations in RWA and SDO do not lend themselves to comparable volumetric variation in neural substrates. In either case, this does not necessarily disprove SJT. |

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| Is/are there any region/s that are related to SDO but not RWA? |
| H4: ACC and insula volumes will be negatively associated with only SDO |
| Linear multiple regression: Fixed model, R2 deviation from zero Alpha level, p = .05 N = 82 participants Power = 0.83 to detect medium effect size, f = .15 |
| ROI multiple regression analysis with RWA and SDO scores as independent variables regressed on mean GMV of ACC and insula, on separate analyses. Age is included as a nuisance variable. |
| We decided on a medium effect size as this study is investigating a fairly new hypothesis. To the best of our knowledge, there has been no published work investigating brain structures that involve both SDO and RWA in a single study. Though previous studies have only measured SDO in relation to fMRI-based research and do not account for RWA scores, neural activity in these areas associated with SDO aligns with a prediction of structural variation in these same brain regions. |
| H4 is supported if the test reveals SDO, but not RWA, have statistically significant negative correlations with both mean ACC and insula volume.  Statistically significant negative correlation between SDO with either ACC or insula volume would provide partial support for H4.  Insignificant correlation of both RWA and SDO with ACC and insula volumes would disconfirm the hypothesis. Significantly positive correlation of either or both RWA and SDO with ACC and insula volumes would also disconfirm the hypothesis. Significantly negative correlation of RWA with ACC and insula would also disconfirm the hypothesis. |
| Dual Process Model; if ACC or insula volumes are found to not correlate with SDO as predicted, similar interpretations can be made as with H2(i.e. other brain regions governing SDO or ACC/insula volumes simply do not covary with SDO self-report scores); if ACC or insula volumes correlate with RWA but not SDO, this may suggest external factors may need to be accounted for in the DPM model, particularly, those that are pertinent to Singapore’s social and political context that may influence how RWA and SDO manifest. |

**Declaration of competing interests**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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**Appendix A**

Items on Right-Wing Authoritarianism Scale

Participants were instructed to rate their agreement or disagreement with each statement from -4 (strongly disagree) through 0 (neutral) to +4 (strongly agree).

1. The established authorities generally turn out to be right about things, while the radicals and protestors are usually just “loud mouths” showing off their ignorance.
2. Women should have to promise to obey their husbands when they get married.
3. Our country desperately needs a mighty leader who will do what has to be done to destroy the radical new ways and sinfulness that are ruining us.
4. Gays and lesbians are just as healthy and moral as anybody else.\*
5. It is always better to trust the judgment of the proper authorities in government and religion than to listen to the noisy rabble-rousers in our society who are trying to create doubt in people’s minds.
6. Atheists and others who have rebelled against the established religions are no doubt every bit as good and virtuous as those who attend church regularly.\*
7. The only way our country can get through the crisis ahead is to get back to our traditional values, put some tough leaders in power, and silence the troublemakers spreading bad ideas.
8. There is absolutely nothing wrong with nudist camps.\*
9. Our country needs free thinkers who have the courage to defy traditional ways, even if this upsets many people.\*
10. Our country will be destroyed someday if we do not smash the perversions eating away at our moral fiber and traditional beliefs.
11. Everyone should have their own lifestyle, religious beliefs, and sexual preferences, even if it makes them different from everyone else.\*
12. The “old-fashioned ways” and the “old-fashioned values” still show the best way to live.
13. You have to admire those who challenged the law and the majority’s view by protesting for women’s abortion rights, for animal rights, or to abolish school prayer.\*
14. What our country really needs is a strong, determined leader who will crush evil, and take us back to our true path.
15. Some of the best people in our country are those who are challenging our government, criticizing religion, and ignoring the “normal way things are supposed to be done.”\*
16. God’s laws about abortion, pornography and marriage must be strictly followed before it is too late, and those who break them must be strongly punished.
17. There are many radical, immoral people in our country today, who are trying to ruin it for their own godless purposes, whom the authorities should put out of action.
18. A “woman’s place” should be wherever she wants to be. The days when women are submissive to their husbands and social conventions belong strictly in the past.\*
19. Our country will be great if we honor the ways of our forefathers, do what the authorities tell us to do, and get rid of the “rotten apples” who are ruining everything.
20. There is no “ONE right way” to live life; everybody has to create their own way.\*
21. Homosexuals and feminists should be praised for being brave enough to defy “traditional family values.\*
22. This country would work a lot better if certain groups of troublemakers would just shut up and accept their group’s traditional place in society.

\*items to be reverse-coded before calculating total RWA score

**Appendix B**

Items on the Social Dominance Orientation Scale

Participants were instructed to rate their agreement or disagreement with each statement from 1 (strongly disagree) to 7 (strongly agree).

1. Some groups of people are simply inferior to other groups.
2. In getting what you want, it is sometimes necessary to use force against other groups.
3. It's OK if some groups have more of a chance in life than others.
4. To get ahead in life, it is sometimes necessary to step on other groups.
5. If certain groups stayed in their place, we would have fewer problems.
6. It's probably a good thing that certain groups are at the top and other groups are at the bottom.
7. Inferior groups should stay in their place.
8. Sometimes other groups must be kept in their place.
9. It would be good if groups could be equal.\*
10. Group equality should be our ideal.\*
11. All groups should be given an equal chance in life.\*
12. We should do what we can to equalize conditions for different groups.\*
13. Increased social equality is beneficial to society.\*
14. We would have fewer problems if we treated people more equally.\*
15. We should strive to make incomes as equal as possible.\*
16. No group should dominate in society.\*

\*items to be reverse-coded before calculating total SDO score