Personality and Individual Differences 141 (2019) 200–208

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

The psychological roots of intellectual humility: The role of intelligence and cognitive flexibility

Leor Zmigrod[a,b,*], Sharon Zmigrod[a,c], Peter Jason Rentfrow[a], Trevor W. Robbins[a,b]

[a] Department of Psychology, University of Cambridge, Cambridge, United Kingdom
[b] Behavioural and Clinical Neuroscience Institute, University of Cambridge, Cambridge, United Kingdom
[c] Leiden University Institute for Psychological Research & Leiden Institute for Brain and Cognition, Leiden, the Netherlands

ARTICLE INFO

Keywords:
Intellectual humility
Cognitive flexibility
Intelligence
Cognition
Humility
Interaction

ABSTRACT

Intellectual humility has been identified as a character virtue that allows individuals to recognize their own potential fallibility when forming and revising attitudes. Intellectual humility is therefore essential for avoiding confirmation biases when reasoning about evidence and evaluating beliefs. The present study investigated the cognitive correlates of intellectual humility. The results indicate that cognitive flexibility, measured with objective behavioural assessments, predicted intellectual humility. Intelligence was also predictive of intellectual humility. These relationships were particularly pronounced for the facets of intellectual humility associated with respect for opposing opinions and openness to revising one's attitudes in light of new evidence. The data revealed an interaction: high cognitive flexibility is particularly valuable for intellectual humility in the context of low intelligence, and reciprocally, high intelligence was beneficial for intellectual humility in the context of low flexibility. Notably, there was evidence of a compensatory effect, as participants who scored highly on both flexibility and intelligence did not exhibit superior intellectual humility relative to individuals who scored highly on only one of these cognitive traits. These findings are suggestive of dual psychological pathways to intellectual humility; either cognitive flexibility or intelligence are sufficient for high intellectual humility, but neither is necessary.

1. Introduction

In an era of polarization, fake news, and the wide spread of misinformation, there is a strong public need for an understanding of how citizens can inoculate themselves against deception and inaccurate information. The capacity to critically evaluate information in nonbiased ways requires *intellectual humility* – the understanding of one's limitations and biases when making evidence-based decisions. Intellectual humility allows us to avoid psychological tendencies to overlook evidence and confirm prior beliefs. Specifically, intellectual humility has been defined as "recognizing that a particular personal belief may be fallible, accompanied by an appropriate attentiveness to limitations in the evidentiary basis of that belief and to one's own limitations in obtaining and evaluating relevant information" (Leary et al., 2017).

Over the last decade, a substantial literature has emerged in philosophy, theology, and psychology, seeking to (a) define intellectual humility (Baehr, 2011; Davis et al., 2016; Gregg, Mahadevan, & Sedikides, 2017; Roberts & Wood, 2003; Samuelson et al., 2015; Whitcomb, Battaly, Baehr, & Howard-Snyder, 2015; Wright et al., 2017), (b) develop measurement tools (Hoyle, Davisson, Diebels, & Leary, 2016; Krumrei-Mancuso & Rouse, 2016; Leary et al., 2017; McElroy et al., 2014; Meagher, Leman, Bias, Latendresse, & Rowatt, 2015), and (c) link intellectual humility to other personality traits such as openness (McElroy et al., 2014; Porter & Schumann, 2018; Leary et al., 2017), prosociality (Krumrei-Mancuso, 2017), dispositional attachment orientation (Jarvinen & Paulus, 2017), and religiosity and religious tolerance (Hopkin, Hoyle, & Toner, 2014; Hook et al., 2017; Krumrei-Mancuso, 2018; Leary et al., 2017; Rodriguez et al., 2017; Van Tongeren et al., 2016; Zhang et al., 2018). So far, research on the psychological roots of intellectual humility has been primarily the concern of social and developmental psychology.

In theorising about the cognitive mechanisms that might underlie intellectual humility, Samuelson and Church (2015) proposed that the human tendency to rely on heuristics may lead to intellectually arrogant behaviours. Dual-systems accounts of human cognition suggest that thinking and reasoning are characterized by two distinct systems: System 1 processes, which are fast, automatic, associative, and intuitive, and System 2 processes, which are slow, conscious, deliberate,

* Corresponding author at: Department of Psychology, University of Cambridge, CB2 3EB Cambridge, United Kingdom.
E-mail address: lz343@cam.ac.uk (L. Zmigrod).

https://doi.org/10.1016/j.paid.2019.01.016
Received 28 September 2018; Received in revised form 13 December 2018; Accepted 9 January 2019
Available online 15 January 2019

and analytical (Evans, 2003, 2008; Evans & Stanovich, 2013; Kahneman & Frederick, 2002). The corollary of this dual-systems approach is that in order to reason intelligently and avoid biased thinking, it is necessary to engage System 2 processes which are deliberate and analytical, and to override the automatic biases that are assumed to emerge from System 1 processes (Evans, 2003, 2008). Samuelson and Church (2015) therefore suggest that in order to facilitate intellectual humility, System 2 processes must be engaged and promoted. Interestingly, De keersmaecker and Roets (2017) found that cognitive ability shaped the extent to which individuals adjust their beliefs after learning that their attitudes were based on false information; people with lower levels of cognitive ability adjust their attitudes to a lesser extent than those with higher levels of cognitive ability. Intelligence may therefore be an important cognitive correlate of intellectual humility.

Nevertheless, although deliberate, intelligent, analytical thinking may be important for intellectual humility, it might not be sufficient or necessary. For instance, one can persist in believing one's previous ideas and resist changing them in the face of new evidence even with slow and deliberative thinking. Intellectual humility and the capacity to revise one's ideas and be open to the ideas of others may require more than just analytical thinking or cognitive ability. Specifically, in order to be aware of one's cognitive limitations and evaluate evidence appropriately, considerable mental flexibility is required. While the intellectually arrogant or servile individual disregards new information in favour of past beliefs, the intellectually humble individual is able to be flexible in their thinking, overcome biased reasoning, find creative connections between past ideas and new information, and flexibly adjust their attitudes based on new evidence. The aim of this study was therefore to evaluate the hypothesis that *the intellectually humble mind is also a flexible mind*.

The hypothesis that cognitive flexibility and openness to novel ideas may be crucial ingredients for intellectual humility has support in the empirical literature. Indeed, Leary et al. (2017) found that intellectual humility was positively correlated with self-reported openness to alternative ideas and values, and negatively correlated with dogmatism and intolerance of ambiguity. Stanovich and West (1997) found that participants who scored highly on a self-report measure called "Actively Open-minded Thinking", which the researchers suggested is an indicator of cognitive flexibility and openness to belief change, were more likely to evaluate arguments based on the argument quality rather than relying on prior beliefs, even when controlling for cognitive ability. The study therefore suggests that a flexible thinking disposition may facilitate intellectual humility independently of cognitive ability. Interestingly, cognitive ability, operationalized with SAT scores and a test of verbal ability, was a unique and independent predictor of argument evaluation performance, signifying intelligence may still play a notable role.

However, there are methodological problems with relying purely on self-report measures of cognitive flexibility. For instance, effect sizes may be inflated in self-report as compared to behavioural measures of cognition, and at times self-report measures yield opposite effects to theoretically-consistent behavioural assessments (e.g. Van Hiel, Onraet, Crowson, & Roets, 2016; De Keersmaecker et al., 2017; Saunders, Milyavskaya, Etz, Randles, & Inzlicht, 2018). Furthermore, new tools have been developed to accurately measure intellectual humility and its components directly (Krumrei-Mancuso & Rouse, 2016), and so there is a need to empirically investigate the ways in which flexibility of thought can shape intellectual humility.

The present study sought to disentangle the relationships between cognitive flexibility, cognitive ability (fluid intelligence), and intellectual humility, using classic tasks from experimental psychology. Notably, cognitive flexibility and intelligence have been theoretically and empirically dissociated (e.g. Friedman et al., 2006; Salthouse, Fristoe, McGuthry, & Hambrick, 1998; Schaie, Dutta, & Willis, 1991), and so it is valuable to examine their relative contributions and interactions. This investigation thus addressed three primary hypotheses:

H1. Flexible thinking is positively correlated with intellectual humility (building on Stanovich and West's (1997) work).

H2. Cognitive ability is positively correlated with intellectual humility (as suggested by Samuelson & Church, 2015 and De keersmaecker & Roets, 2017).

H3. There is an interaction between flexibility and intelligence in shaping intellectual humility. If indeed intellectual humility is associated with high cognitive flexibility (in H1) and high intelligence (in H2), then two plausible, dissociative interaction mechanisms might be at play:

H3-A There is an *additive or multiplicative interaction*, such that the highest intellectual humility would reflect high flexibility and high intelligence, while the lowest intellectual humility would be associated with low flexibility and low intelligence. This hypothesis would predict that individuals who score highly on flexibility, but not intelligence (and vice versa), would have lower intellectual humility than individuals who score highly on both.

H3-B There is a *compensatory interaction*, such that either high flexibility or high intelligence are sufficient for high intellectual humility. Consequently, high flexibility would facilitate intellectual humility particularly for individuals with lower scores on the intelligence test, and vice versa. This hypothesis would predict that individuals who score highly on flexibility, but not intelligence (and vice versa), would have similar levels of intellectual humility as individuals who score highly on both. That is, there is no additive advantage for intellectual humility in scoring highly on both flexibility and intelligence. This would suggest that there are multiple independent psychological pathways to achieving high intellectual humility.

The present study sought to investigate the cognitive correlates of intellectual humility and clarify these mechanisms in order to better understand the psychological underpinnings of intellectual humility and its various facets.

2. Method

In accordance with the guidelines by Simmons, Nelson, and Simonsohn (2012), we report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study. Relevant data and code will be available on the Open Science Framework repository upon publication.

2.1. Participants

108 participants completed the study in full (see Supplementary Information SI1 for further details). Participants provided their informed consent to participate in the study in accordance with the institution's Department of Psychology Ethics Committee approval. Power analysis was conducted to compute the required sample size (see Supplementary Information SI1 for further details), with the 'pwr' package (Champely, 2015) in R (R Core Team, 2017).

2.2. Measures

2.2.1. Intellectual humility – comprehensive intellectual humility scale (CIHS)

The CIHS, a 22-item scale developed by Krumrei-Mancuso and Rouse (2016), was used to assess intellectual humility. The CIHS scale measures four distinct factors of intellectual humility: (1) independence of intellect and ego (Cronbach's $\alpha = 0.914$; e.g. "When someone contradicts my most important beliefs, it feels like a personal attack"), (2) openness to revising one's viewpoint (Cronbach's $\alpha = 0.872$; e.g. "I am open to revising my important beliefs in the face of new information"), (3) respect for others' viewpoints (Cronbach's $\alpha = 0.926$; e.g. "I can respect others, even if I disagree with them in important ways"), and (4)

lack of intellectual overconfidence (Cronbach's α = 0.822; e.g. "My ideas are usually better than other people's ideas"). The items are rated on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). Items were summed for the full scale (Cronbach's α = 0.664) and for each of the subscales (factors). Higher scores indicated greater intellectual humility.

2.2.2. Cognitive flexibility – alternate uses task (AUT)

In this computerized version of the AUT (Guilford, 1967), two common household items (brick and newspaper) were presented each for 1.5 min. Participants were asked to generate as many possible uses for these items. A timed clock was displayed to participants showing them how much time they had left. Flexibility was quantified as the total number of distinct conceptual categories in which the participant's responses belonged, in accordance with convention (e.g. Addis, Pan, Musicaro, & Schacter, 2016; Chermahini & Hommel, 2010; Madore, Addis, & Schacter, 2015). The responses were rated and calculated by two independent raters.

Cognitive Flexibility - Verbal Fluency task (VF).

In this computerized version of the semantic verbal fluency (Tombaugh, Kozak, & Rees, 1999; Troyer, Moscovitch, & Winocur, 1997), participants are asked to generate words from a given concept (i.e. '*things on wheels*' or '*red things*') for 2 min each. Flexibility was computed as the total number of distinct conceptual categories. The responses were rated and calculated by two independent raters.

2.2.3. Intelligence - Raven's standard progressive matrices task (Raven's SPM)

An abbreviated version of the Raven's SPM (Bilker et al., 2012; Raven, 1938) was used to assess fluid intelligence. The task was composed of nine visual patterns which progressively increased in difficulty. For each matrix pattern, one piece was missing, and participants are asked to select the correct pattern piece from a set of possible solutions.

3. Results

All analyses were conducted in R (R Core Team, 2017) and SPSS (Version 25.0; IBM Corp., 2017), including the R packages visreg (Breheny & Burchett, 2017), jtools (Long, 2018), and pwr (Champely, 2015). First, we investigated whether the demographic variables of age, gender, and educational attainment, were related to the psychological variables of interest. Age was not significantly correlated with cognitive flexibility measured with the AUT ($r = 0.06$, $p = .521$), cognitive flexibility measured with the VF task ($r = 0.011$, $p = .908$), fluid intelligence measured with Raven's SPM ($r = 0.037$, $p = .703$), or with the comprehensive intellectual humility score ($r = 0.056$, $p = .567$). Furthermore, there were no gender differences in AUT cognitive flexibility, $t(106) = 0.68$, $p = .501$, VF cognitive flexibility, $t(106) = -0.60$, $p = .552$, or in intellectual humility, $t(106) = -1.03$, $p = .306$. There was a gender difference in Raven's SPM scores in the current sample, $t(106) = 2.14$, $p = .035$, in which males scored higher than females. Educational attainment was significantly correlated with AUT Flexibility ($r = 0.23$, $p = .002$) and Raven's SPM ($r = 0.31$, $p = .001$), nearly significantly correlated with VF Flexibility ($r = 0.18$, $p = .060$), and not correlated with intellectual humility ($r = 0.06$, $p = .552$). In all subsequent statistical analyses, age, gender, and educational attainment were included as covariates.

3.1. H1: Is intellectual humility positively correlated with cognitive flexibility?

Correlational analysis revealed that cognitive flexibility measured with the AUT was significantly positively correlated with general intellectual humility (Fig. 1A). Furthermore, as evident in Fig. 2, decomposing the Comprehensive Intellectual Humility scale into its constituent factors revealed that this association was primarily driven by the correlations of cognitive flexibility with openness to revising one's viewpoint (Factor 2) and respect for others' viewpoints (Factor 3). Given Gignac and Szodorai's (2016) effect size guidelines for individual differences research, these effect sizes can be considered moderate to large.

This pattern was corroborated by the correlations of intellectual humility and cognitive flexibility measured with the Verbal Fluency (VF) task. VF Flexibility was positively correlated with the comprehensive intellectual humility scale ($r = 0.26$, $p = .007$), and specifically with openness to revising one's viewpoint (Factor 2; $r = 0.29$, $p = .002$) and respect for others' viewpoints (Factor 3; $r = 0.24$, $p = .014$). There were no significant correlations between VF cognitive flexibility and independence of intellectual ego (Factor 1; $r = 0.12$, $p = .207$) or lack of intellectual overconfidence ($r = 0.09$, $p = .339$), paralleling the findings for AUT cognitive flexibility.

3.2. H2: Is intellectual humility positively correlated with intelligence?

As depicted in Fig. 1B and Fig. 2B, intellectual humility was significantly positively correlated with fluid intelligence, such that more intellectually humble individuals tended to score more highly on Raven's SPM. Similarly to the pattern of results revealed for cognitive flexibility, intelligence was specifically positively correlated to the factors of intellectual humility representing openness to revising one's viewpoint (Factor 2) and respect for others' viewpoints (Factor 3; Fig. 2). The correlation effect sizes were generally smaller for the relationship between intellectual humility and intelligence than for intellectual humility and cognitive flexibility.

3.3. H3: What is the relationship between cognitive flexibility and intelligence in shaping intellectual humility?

In order to investigate whether, and in what way, cognitive flexibility and intelligence interact to produce heightened intellectual humility, hierarchical linear regression analysis predicting general intellectual humility was conducted (Table 1). Note that all independent variables were centred prior to the hierarchical linear regression, as this helps reduce multicollinearity and facilitates testing of simple slopes (Dawson & Richter, 2006). In Step 1, the control variables, including age, gender, and educational attainment, were entered. As shown in Table 1, none of these control variables significantly predicted intellectual humility. In Step 2, the centred cognitive flexibility and centred fluid intelligence scores were entered. These independent variables explained a significant proportion of the variance in intellectual humility ($R^2 = 0.17$). As evident in Table 1, the coefficients of both cognitive flexibility and intelligence were positive and significant, suggesting that both positively predicted heightened intellectual humility and each was a unique predictor. Next, in Step 3, we entered the interaction term for cognitive flexibility and intelligence. As predicted, the interaction of flexibility and intelligence was significant and accounted for an additional 5.5% of the variance in intellectual humility.

Simple slope analyses were conducted to examine the relationship between intellectual humility and flexibility at 1 *SD* above and below mean intelligence, while controlling for age, gender, and educational attainment as covariates (see Fig. 3A). These analyses revealed that flexibility was positively related to intellectual humility in the context of low intelligence (at −1 *SD*, $b = 6.24$, SE = 1.51, $p < .001$) but not high intelligence (at +1 *SD*, $b = -0.39$, SE = 1.87, $p = .834$). Reciprocally, simple slope analyses demonstrated that when flexibility is conceptualized as the moderator, intellectual humility was positively related to intelligence in the context of low flexibility (at −1 *SD*, $b = 2.43$, SE = 0.72, $p < .001$), but not for high flexibility (at +1 *SD*, $b = -0.51$, SE = 0.78, $p = .516$).

To validate this finding further, the sample was divided into three equal groups (terciles) rather than according to deviation from the

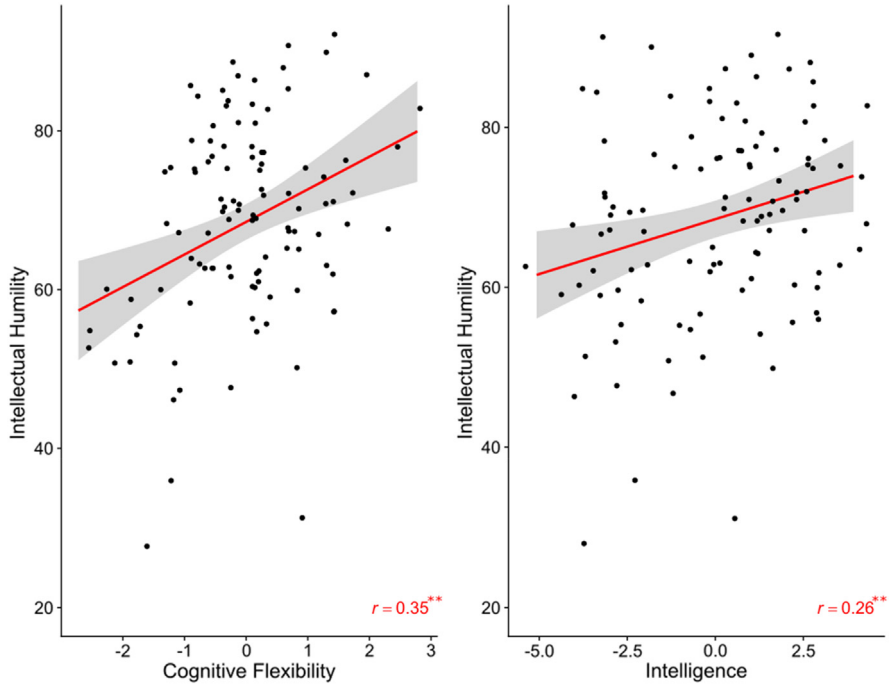

Fig. 1. Correlation between Comprehensive Intellectual Humility and (A) cognitive flexibility (centred and measured with the AUT) and (B) intelligence (centred and measured with Raven's SPM). Confidence intervals reflect 95% CI. $^{**}p < .01$.

mean. The simple slope analysis results were unchanged following this robustness check; cognitive flexibility was positively related to intellectual humility in the context of low intelligence (at −2.67 *SD*, $b = 6.64$, SE = 1.61, $p < .001$) but not average intelligence (at +0.5 *SD*, $b = 2.23$, SE = 1.25, $p = .078$) and high intelligence (at +2.71 *SD*, $b = -0.85$, SE = 2.01, $p = .674$). Reciprocally, intelligence was positively related to intellectual humility in the context of low flexibility (at −0.87 *SD*, $b = 2.16$, SE = 0.66, $p = .001$), but not for average (at +0.28 *SD*, $b = 0.57$, SE = 0.55, $p = .300$) or high flexibility (at +1.23 *SD*, $b = -0.75$, SE = 0.85, $p = .381$).

This interaction effect is visualized in the filled contour plot and the corresponding 3D perspective plot in Fig. 4. This depicts that the relationship between intellectual humility and cognitive flexibility varies depending on intelligence, such that intelligence differentiates between low and high intellectual humility at low levels of cognitive flexibility, but not at high levels of cognitive flexibility. Similarly, cognitive flexibility differentiates between low and high intellectual humility at low intelligence scores, but not high intelligence scores. Moreover, Fig. 4 illustrates that the highest intellectual humility was evident in participants who scored highly on either intelligence or flexibility, and that scoring highly on both is not related to higher intellectual humility. Fig. 4 also highlights a slight bias toward higher intellectual humility scores amongst those with high cognitive flexibility (but low intelligence) relative to those with high intelligence (but low flexibility), which is also reflected in the higher regression coefficients in Table 1 for cognitive flexibility relative to intelligence.

To probe the interaction further, we applied the Johnson-Neyman technique (Bauer & Curran, 2005; Hayes & Matthes, 2009; Johnson & Neyman, 1936), which calculates the range of *z* values of the moderator (in this case, intelligence) in which the predictor (i.e. cognitive flexibility) is a significant versus nonsignificant predictor of the outcome (i.e. intellectual humility). This helps to avoid limitations of traditional simple slopes analysis which require selection of potentially arbitrary values of the moderator at which the relationship between the predictor and outcome variable are assessed (e.g. ± 1 SD from the mean). This technique is increasingly used in the psychological and cognitive sciences (e.g. Beach et al., 2012; Bushman, Giancola, Parrott, & Roth, 2012; Salerno & Peter-Hagene, 2013).

Furthermore, Esarey and Sumner (2017) pointed out that probing interactions in the traditional way can lead to a multiple comparison problem. To address this, we implemented the method proposed by Esarey and Sumner (2017) to control for multiple comparisons; this leads to a more conservative test in which the false discovery rate in the marginal effects plot is controlled.

The findings from the Johnson-Neyman analysis demonstrated that the relationship between intellectual humility and cognitive flexibility was significant when intelligence was less than 0.19 *SD* above the mean, but not significant with higher values of intelligence (Fig. 3B). This mirrors the finding from the simple slopes interaction analysis (Fig. 3A), in which the relationship between intellectual humility and cognitive flexibility is significant at low intelligence (−1 *SD*). In accordance with the methodological suggestions of McClelland, Irwin, Disatnik, and Sivan (2017), Spiller, Fitzsimons, Lynch Jr, and McClelland (2013), and Bauer and Curran (2005), this is revealed graphically in Fig. 3B. In Fig. 3B, the transition between significance and non-significance of the conditional effect is indicated by the dashed vertical line, which represents the Johnson-Neyman point at which the 95% confidence band intersects the *x*-axis. In accordance with Esarey and Sumner's (2017) recommendation, the Johnson-Neyman interval was calculated using the false discovery rate adjusted $t = 2.21$; note that when not adjusted for multiple comparisons using Esarey and Sumner's (2017) methodology, the Johnson-Neyman point is +0.35 *SD*.

Although we conceptualized intelligence as the moderator of the relationship between intellectual humility and cognitive flexibility, it is important to note that the choice of moderator for analyses is arbitrary – cognitive flexibility could have equally been used as the moderator with paralleling results. We chose to use intelligence as the moderator here because it is largely considered a highly genetically heritable and stable construct, while there is more discussion over the stability and malleability of cognitive flexibility (e.g. Miyake & Friedman, 2012). Nonetheless, as evident in the filled contour plot of Fig. 4A, there is a symmetry in the interaction effect, such that the relationship between intellectual humility and intelligence is most pronounced at low levels of cognitive flexibility, and similarly the relationship between

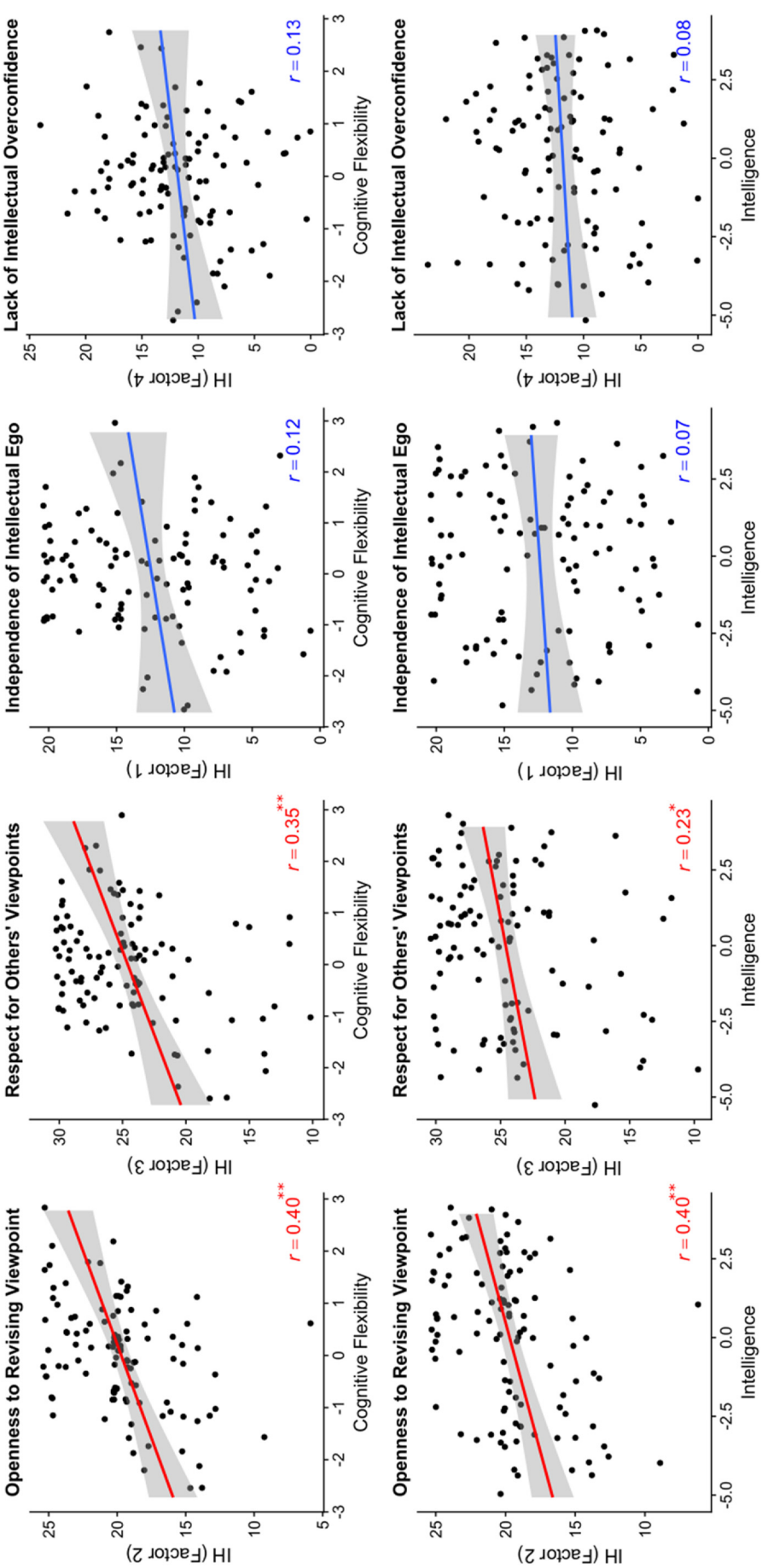

Fig. 2. Correlations between specific factors of intellectual humility (IH) and cognitive flexibility (top row) and intelligence (bottom row). Confidence intervals reflect 95% CI. $^{*}p < .05$, $^{**}p < .01$, red = significant correlation, blue = nonsignificant. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Hierarchical multiple linear regression predicting scores on the Comprehensive Intellectual Humility Scale. Intelligence measured via Raven's scores and Flexibility assessed by the AUT Flexibility score. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Dependent Variable: Comprehensive Intellectual Humility	*B*	*Standard error (B)*	*95% CI*	*ß*	*p*
Step 1					
Age	0.058	0.107	[−0.154, 0.271]	0.053	.587
Gender	2.512	2.439	[−2.324, 7.349]	0.101	.305
Education	0.671	0.937	[−1.186, 2.528]	0.070	.475
$R^2 = 0.017$; $F(3,104) = 0.601$, $p = .616$					
Step 2					
Age	0.011	0.100	[−0.187, 0.210]	0.010	.910
Gender	3.827	2.308	[−0.750, 8.405]	0.153	.100
Education	−0.795	0.935	[−0.2648, 1.059]	−0.083	.397
Intelligence	1.069	0.535	[0.007, 2.130]	0.204	.048*
Flexibility	3.596	1.183	[1.250, 5.942]	0.304	.003**
$R^2 = 0.170$; $F(5,102) = 4.167$, $p = .002^{**}$					
Step 3					
Age	0.029	0.098	[−0.164, 0.223]	0.026	.766
Gender	2.939	2.264	[−1.552, 7.430]	0.118	.197
Education	−0.896	0.908	[−2.697, 0.905]	−0.094	.326
Intelligence	0.960	0.521	[−0.073, 1.993]	0.183	.068
Flexibility	2.924	1.175	[0.594, 5.254]	0.247	.014*
Intelligence × Flexibility	−1.390	0.515	[−2.412, −0.368]	−0.248	.008**
$R^2 = 0.225$; $F(6,101) = 4.900$, $p < .001^{***}$					

intellectual humility and flexibility is evident at low levels of intelligence.

4. Discussion

Intellectual humility has been identified as a character virtue that enables individuals to recognize their own potential fallibility when forming and revising attitudes and beliefs. The present study examined the relationships between intellectual humility and objectively-assessed cognitive flexibility and fluid intelligence. With regards to our first hypothesis (H1), the results indicate that intellectual humility is positively related to heightened cognitive flexibility (Fig. 1A). Secondly, the findings reveal that intellectual humility is also positively correlated with intelligence (Fig. 1B), corroborating our second hypothesis (H2) and Samuelson and Church's (2013) suggestion that System 2 (i.e. analytical and deliberate) thinking styles are important for engaging in intellectually humble behaviour. These effects were driven by the facets of intellectual humility that correspond to openness to revising one's

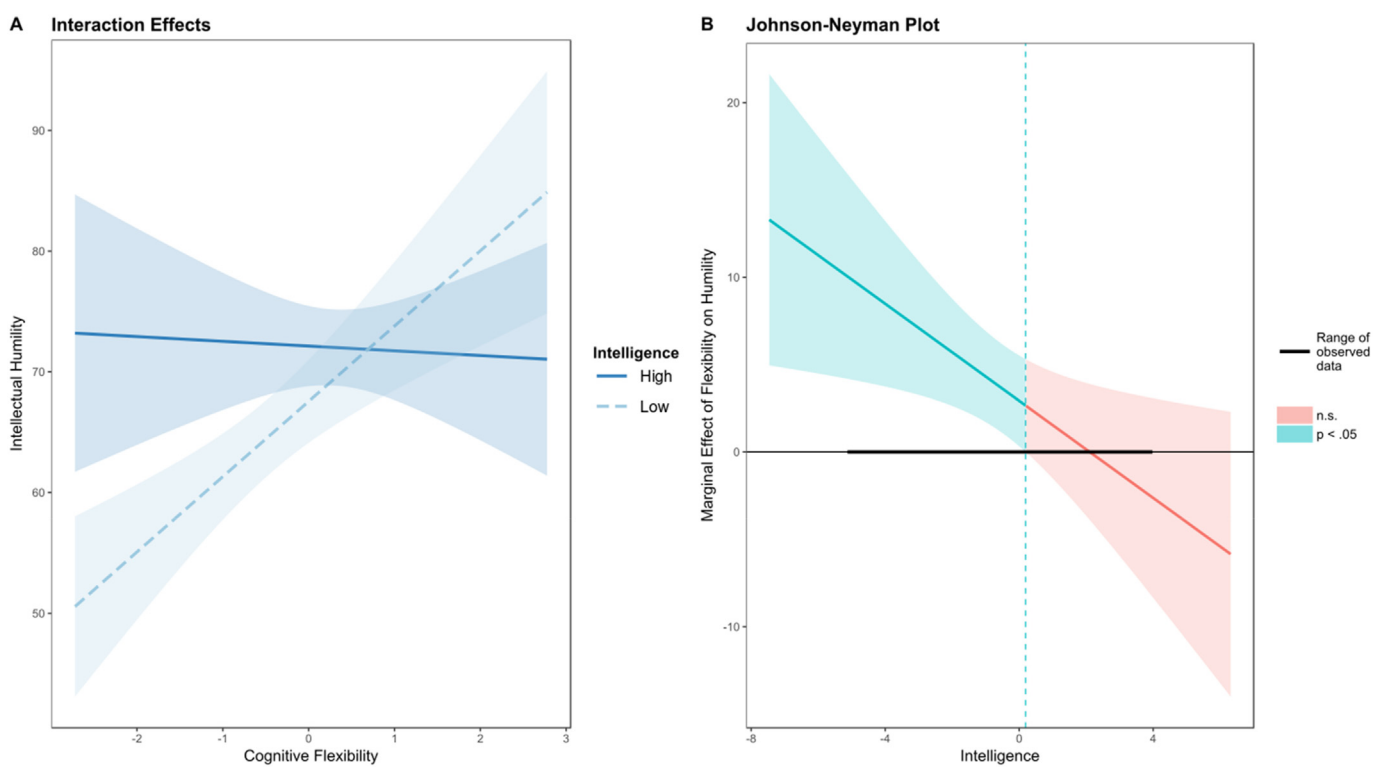

Fig. 3. (A) Interaction plot between comprehensive intellectual humility, cognitive flexibility, and intelligence (high: +1SD, low: -1SD), controlling for age, gender, and educational attainment. (B) Johnson–Neyman regions of significance and confidence bands for the conditional relation between intellectual humility and cognitive flexibility as a function of intelligence. Solid diagonal line represents the regression coefficient of cognitive flexibility for intellectual humility along the intelligence continuum. The dashed vertical line indicates that at +0.19 SD from the intelligence mean value, the regression coefficient of cognitive flexibility as a predictor of intellectual humility transitions from significance to non-significance. Confidence intervals reflect 95% CI.

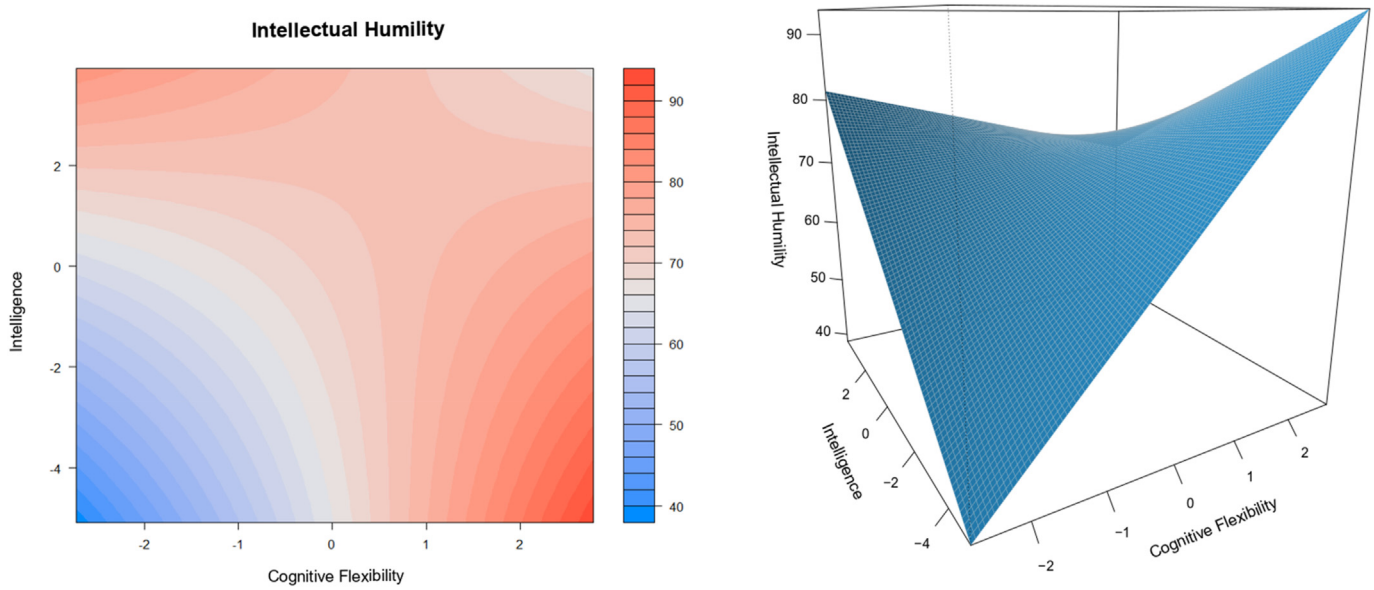

Fig. 4. Representation of the regression surface predicting intellectual humility as a function of cognitive flexibility and intelligence, while controlling for age, gender, and educational attainment. (A) Filled contour plot. Colour gradient reflects comprehensive intellectual humility score. (B) Perspective plot.

viewpoints and respect for others' viewpoints (Fig. 2). Thirdly, the data revealed an interaction between cognitive flexibility and intelligence in predicting intellectual humility (Table 1). Specifically, there was evidence of a facilitation effect, such that high cognitive flexibility is particularly valuable for intellectual humility in the context of low intelligence, and reciprocally, high intelligence was beneficial for intellectual humility in the context of low flexibility (Figs. 3 & 4). Interestingly, there was no evidence of an additive or multiplicative effect (contrary to hypothesis H3-A), as high flexibility and high intelligence did not produce superior intellectual humility relative to individuals who scored highly on only one of these cognitive traits (corroborating hypothesis H3-B; see Fig. 4). This is suggestive of dual psychological pathways to intellectual humility; either cognitive flexibility or intelligence is sufficient for high intellectual humility, but neither is necessary.

The results demonstrate that cognitive flexibility was more strongly implicated in intellectual humility than intelligence, as manifest by the larger effect sizes (in Table 1, Figs. 1, 2, & 4). This may signify that the two pathways may have differential efficacy in producing intellectually humble attitudes and behaviours. Furthermore, the study revealed that not all facets of intellectual humility are equally shaped by cognitive flexibility and intelligence (Fig. 2). While epistemically-oriented features of intellectual humility, such as openness to alternative ideas (captured by Factor 2) and receptivity to attitude change (Factor 3), were positively correlated with both cognitive traits, the aspects of intellectual humility that are more closely associated with intellectual identity, such as the extent to which one feels threatened when contradicted (Factor 1) and one's conviction that one's own beliefs are superior and infallible (Factor 4), were unrelated to cognitive flexibility and intelligence. The specificity of these relationships suggests that future research will need to examine additional psychological and social factors that shape individuals' tendency to be intellectually overconfident.

These findings extend research in three key disciplines: (1) cognitive psychology, (2) social psychology, and (3) interventionist and educational approaches. In the realm of cognitive psychology, recent research has provided corroborating evidence for a positive relationship between intelligence and intellectual humility across the lifespan. Danovitch, Fisher, Schroder, Hambrick, and Moser (2017) investigated biopsychological markers of intellectual humility in 6- to 8-year-old children. They found that greater intellectual humility was related to higher intelligence, and this relationship was specific to the epistemic aspect of intellectual humility (i.e. acknowledging the limitations of one's own knowledge) rather than its social component (i.e. representing one's knowledge to other people and being receptive to their ideas). This mirrors the specificity identified in the present study (Fig. 2). Similarly, developmental work by Mills and Elashi (2014) found that intelligence predicted 6- to 9-year-old children's ability to recognize that a source of information may be worthy of doubt and scepticism. Intelligence may therefore also be linked to early forms of intellectual humility. Additionally, research with adults has illustrated that intellectual humility and receptivity to attitude-change are related to cognitive ability (De keersmaecker & Roets, 2017) and higher discriminability in an old/new recognition memory task (Deffler, Leary, & Hoyle, 2016). Furthermore, Lick, Alter, and Freeman (2018) found that cognitive ability (as measured with Raven's Advanced Progressive Matrices) was related to enhanced updating of social stereotypes in light of new information, supporting the present finding that intelligence may be linked to a willingness to revise one's attitudes based on novel evidence.

These results are also congruent with research in social and political psychology on the psychological correlates of behaviours that may be conceptualized as the opposite of intellectual humility – dogmatism, prejudice, and rigid adherence to ideological doctrines. Intellectual humility has been linked to lower dogmatism and belief superiority (Leary et al., 2017), fewer negative attitudes toward religious outgroups (Van Tongeren et al., 2016), and a willingness to be exposed to opposing political perspectives (Porter & Schumann, 2018). Frimer, Skitka, and Motyl (2017) have illustrated that liberals and conservatives are similarly motivated to avoid exposure to one another's opinions – a key facet of intellectual humility – suggesting that strong adherence to ideologies is related to a tendency to avoid hearing opposing views. Furthermore, recent empirical work has shown that cognitive ability is negatively related to right-wing ideological attitudes, authoritarianism, and prejudice (e.g. Brandt & Crawford, 2016; De Keersmaecker et al., 2017; Ludeke, Rasmussen, & DeYoung, 2017; Choma & Hanoch, 2017; for meta-analysis: Onraet et al., 2015), and that a cognitive style characterized by rigidity and intolerance of ambiguity is positively related to right-wing attitudes (for meta-analyses: Van Hiel et al., 2016; Jost, 2017). Moreover, a recent set of studies have demonstrated that behaviourally-assessed cognitive inflexibility is related to the extent to which individuals adhere firmly and rigidly to ideologies, in the realm of nationalism (Zmigrod, Rentfrow, & Robbins,

2018), politics (Zmigrod, Rentfrow, and Robbins, under review), and religion (Zmigrod, Rentfrow, Zmigrod, & Robbins, 2018). There is therefore converging evidence that intellectual humility and its opposing interpersonal correlate – rigid ideological thinking – are shaped by cognitive ability and cognitive flexibility.

The finding that intellectual humility has multiple distinct psychological underpinnings – an analytical thinking route and a mental flexibility route – provides a fruitful basis on which to expand research into interventions that promote inoculation against misinformation and ideological polarization. Pre-emptively warning individuals about ideologically-motivated efforts to spread misinformation and about the argumentation techniques commonly used in misinformation campaigns has been shown to be effective in neutralizing the effect of misinformation on attitudes (Cook, Lewandowsky, & Ecker, 2017; Van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017). The present findings are complementary to this line of research on inoculating citizens against fake news for several reasons. Firstly, identifying individual differences in cognition that shape individuals' willingness to revise their attitudes may suggest that individuals with certain psychological traits may be more receptive than others to inoculation interventions. Additionally, perhaps interventions that emphasize certain cognitive skills (analytical thinking, flexible thinking, etc.) may be more beneficial for individuals with particular psychological dispositions. Future research that combines the interventionist and individual differences perspective will be fruitful in refining our understanding of these processes. Secondly, these studies have focused on examining the effects of conveying information about expert consensus and potential misinformation campaigns in shaping citizens' attitudes (Van der Linden et al., 2017) and trying to engage individuals' System 2 analytical processing in evaluating evidence. The current findings suggest that fostering mental flexibility and an attentionally-open information processing style may also be a successful focal point for future interventions.

Several potential limitations of the present study highlight future avenues for research. Firstly, it will be valuable to replicate these findings in lab settings and not just online samples, as well as in different cultural contexts, and with complementary measures of intelligence and cognitive flexibility. Since the a priori power analysis we conducted based on relevant effect sizes in the literature recommended a sample size of 92 participants, we computed the power actually achieved for the multiple regression models. This revealed that the power was 99.29% ($f^2 = 0.290$), suggesting that the analyses were well powered to detect the present effects. Larger samples in future studies will help to corroborate and generalize these findings.

In outlining future directions for the field, Leary et al. (2017) identified that "of particular interest are ways in which people who are high versus low in intellectual humility may differ in how they process information" (p. 810). The present study addressed this question by illustrating that analytical as well as flexible cognitive processing styles predict heightened intellectual humility. Admitting intellectual fallibility helps facilitate more constructive reactions to disagreements and conflict resolution (Porter & Schumann, 2018). Consequently, identifying and cultivating the cognitive factors shaping intellectual humility may be a key endeavour in building more evidence-based, tolerant, and effective discussions about the contested issues that divide and polarize our societies today.

Conflict of interest

All authors have declared that they have no conflict of interest.

Acknowledgements

We would like to thank Jildou Talman and Angelica Fischer for their assistance in coding the Alternative Uses Test responses. The research was supported by the Gates Cambridge Trust scholarship to L.Z.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.paid.2019.01.016.

References

Addis, D. R., Pan, L., Musicaro, R., & Schacter, D. L. (2016). Divergent thinking and constructing episodic simulations. *Memory, 24*(1), 89–97.
Baehr, J. S. (2011). *The inquiring mind: On intellectual virtues and virtue epistemology.* Oxford University Press.
Bauer, D. J., & Curran, P. J. (2005). Probing interactions in fixed and multilevel regression: Inferential and graphical techniques. *Multivariate Behavioral Research, 40*(3), 373–400.
Beach, S. R., Lei, M. K., Brody, G. H., Simons, R. L., Cutrona, C., & Philibert, R. A. (2012). Genetic moderation of contextual effects on negative arousal and parenting in African-American parents. *Journal of Family Psychology, 26*(1), 46.
Bilker, W. B., Hansen, J. A., Brensinger, C. M., Richard, J., Gur, R. E., & Gur, R. C. (2012). Development of abbreviated nine-item forms of the Raven's standard progressive matrices test. *Assessment, 19*(3), 354–369.
Brandt, M. J., & Crawford, J. T. (2016). Answering unresolved questions about the relationship between cognitive ability and prejudice. *Social Psychological and Personality Science, 7*(8), 884–892.
Breheny, P., & Burchett, W. (2017). Visualization of regression models using visreg. *The R Journal, 9*, 56–71. https://cran.r-project.org/web/packages/visreg/index.html.
Bushman, B. J., Giancola, P. R., Parrott, D. J., & Roth, R. M. (2012). Failure to consider future consequences increases the effects of alcohol on aggression. *Journal of Experimental Social Psychology, 48*(2), 591–595.
Champely, S. (2015). pwr: Basic functions for power analysis. *R package version, 1(1)*.
Chermahini, S. A., & Hommel, B. (2010). The (b) link between creativity and dopamine: Spontaneous eye blink rates predict and dissociate divergent and convergent thinking. *Cognition, 115*(3), 458–465.
Choma, B. L., & Hanoch, Y. (2017). Cognitive ability and authoritarianism: Understanding support for Trump and Clinton. *Personality and Individual Differences, 106*, 287–291.
Cook, J., Lewandowsky, S., & Ecker, U. K. (2017). Neutralizing misinformation through inoculation: Exposing misleading argumentation techniques reduces their influence. *PLoS One, 12*(5), e0175799.
Danovitch, J. H., Fisher, M., Schroder, H., Hambrick, D. Z., & Moser, J. (2017). Intelligence and neurophysiological markers of error monitoring relate to children's intellectual humility. *Child Development*. https://doi.org/10.1111/cdev.12960.
Davis, D. E., Rice, K., McElroy, S., DeBlaere, C., Choe, E., Van Tongeren, D. R., & Hook, J. N. (2016). Distinguishing intellectual humility and general humility. *The Journal of Positive Psychology, 11*(3), 215–224.
Dawson, J. F., & Richter, A. W. (2006). Probing three-way interactions in moderated multiple regression: Development and application of a slope difference test. *Journal of Applied Psychology, 91*(4), 917.
De keersmaecker, J., & Roets, A. (2017). 'Fake news': Incorrect, but hard to correct. The role of cognitive ability on the impact of false information on social impressions. *Intelligence, 65*, 107–110.
De Keersmaecker, J., Roets, A., Dhont, K., Van Assche, J., Onraet, E., & Van Hiel, A. (2017). Need for closure and perceived threat as bases of right-wing authoritarianism: A longitudinal moderation approach. *Social Cognition, 35*(4), 433–449.
Deffler, S. A., Leary, M. R., & Hoyle, R. H. (2016). Knowing what you know: Intellectual humility and judgments of recognition memory. *Personality and Individual Differences, 96*, 255–259.
Esarey, J., & Sumner, J. L. (2017). Marginal effects in interaction models: Determining and controlling the false positive rate. *Comparative Political Studies,* 1–33. (Advance online publication) https://doi.org/10.1177/0010414017730080.
Evans, J. S. B. (2003). In two minds: Dual-process accounts of reasoning. *Trends in Cognitive Sciences, 7*(10), 454–459.
Evans, J. S. B. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology, 59*, 255–278.
Evans, J. S. B., & Stanovich, K. E. (2013). Dual-process theories of higher cognition: Advancing the debate. *Perspectives on Psychological Science, 8*(3), 223–241.
Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science, 17*(2), 172–179.
Frimer, J. A., Skitka, L. J., & Motyl, M. (2017). Liberals and conservatives are similarly motivated to avoid exposure to one another's opinions. *Journal of Experimental Social Psychology, 72*, 1–12.
Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences, 102*, 74–78.
Gregg, A. P., Mahadevan, N., & Sedikides, C. (2017). Intellectual arrogance and intellectual humility: Correlational evidence for an evolutionary-embodied-epistemological account. *The Journal of Positive Psychology, 12*(1), 59–73.
Guilford, J. P. (1967). Creativity: Yesterday, today and tomorrow. *The Journal of Creative Behavior, 1*(1), 3–14.
Hayes, A. F., & Matthes, J. (2009). Computational procedures for probing interactions in OLS and logistic regression: SPSS and SAS implementations. *Behavior Research Methods, 41*(3), 924–936.
Hook, J. N., Farrell, J. E., Johnson, K. A., Van Tongeren, D. R., Davis, D. E., & Aten, J. D. (2017). Intellectual humility and religious tolerance. *The Journal of Positive Psychology, 12*(1), 29–35.

Hopkin, C. R., Hoyle, R. H., & Toner, K. (2014). Intellectual humility and reactions to opinions about religious beliefs. *Journal of Psychology and Theology, 42*(1), 50–61.
Hoyle, R. H., Davisson, E. K., Diebels, K. J., & Leary, M. R. (2016). Holding specific views with humility: Conceptualization and measurement of specific intellectual humility. *Personality and Individual Differences, 97*, 165–172.
Jarvinen, M. J., & Paulus, T. B. (2017). Attachment and cognitive openness: Emotional underpinnings of intellectual humility. *The Journal of Positive Psychology, 12*(1), 74–86.
Johnson, P. O., & Neyman, J. (1936). Tests of certain linear hypotheses and their application to some educational problems. *Statistical research memoirs*.
Jost, J. T. (2017). Ideological asymmetries and the essence of political psychology. *Political Psychology, 38*(2), 167–208.
Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. *Heuristics and Biases: The psychology of intuitive judgment. 49. Heuristics and Biases: The psychology of intuitive judgment* (pp. 81–). .
Krumrei-Mancuso, E. J. (2017). Intellectual humility and prosocial values: Direct and mediated effects. *The Journal of Positive Psychology, 12*(1), 13–28.
Krumrei-Mancuso, E. J. (2018). Intellectual humility's links to religion and spirituality and the role of authoritarianism. *Personality and Individual Differences, 130*, 65–75.
Krumrei-Mancuso, E. J., & Rouse, S. V. (2016). The development and validation of the comprehensive intellectual humility scale. *Journal of Personality Assessment, 98*(2), 209–221.
Leary, M. R., Diebels, K. J., Davisson, E. K., Jongman-Sereno, K. P., Isherwood, J. C., Raimi, K. T., ... Hoyle, R. H. (2017). Cognitive and interpersonal features of intellectual humility. *Personality and Social Psychology Bulletin, 43*(6), 793–813.
Lick, D. J., Alter, A. L., & Freeman, J. B. (2018). Superior pattern detectors efficiently learn, activate, apply, and update social stereotypes. *Journal of Experimental Psychology: General, 147*(2), 209.
Long, J. A. (2018). jtools: Analysis and presentation of social scientific data. *R package version 1.1.1*https://cran.r-project.org/package=jtools.
Ludeke, S. G., Rasmussen, S. H., & DeYoung, C. G. (2017). Verbal ability drives the link between intelligence and ideology in two American community samples. *Intelligence, 61*, 1–6.
Madore, K. P., Addis, D. R., & Schacter, D. L. (2015). Creativity and memory: Effects of an episodic-specificity induction on divergent thinking. *Psychological Science, 26*(9), 1461–1468.
McClelland, G. H., Irwin, J. R., Disatnik, D., & Sivan, L. (2017). Multicollinearity is a red herring in the search for moderator variables: A guide to interpreting moderated multiple regression models and a critique of Iacobucci, Schneider, Popovich, and Bakamitsos (2016). *Behavior Research Methods, 49*(1), 394–402.
McElroy, S. E., Rice, K. G., Davis, D. E., Hook, J. N., Hill, P. C., Worthington, E. L., Jr., & Van Tongeren, D. R. (2014). Intellectual humility: Scale development and theoretical elaborations in the context of religious leadership. *Journal of Psychology and Theology, 42*(1), 19–30.
Meagher, B. R., Leman, J. C., Bias, J. P., Latendresse, S. J., & Rowatt, W. C. (2015). Contrasting self-report and consensus ratings of intellectual humility and arrogance. *Journal of Research in Personality, 58*, 35–45.
Mills, C. M., & Elashi, F. B. (2014). Children's skepticism: Developmental and individual differences in children's ability to detect and explain distorted claims. *Journal of Experimental Child Psychology, 124*, 1–17.
Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8–14.
Onraet, E., Van Hiel, A., Dhont, K., Hodson, G., Schittekatte, M., & De Pauw, S. (2015). The association of cognitive ability with right-wing ideological attitudes and prejudice: A meta-analytic review. *European Journal of Personality, 29*(6), 599–621.
Porter, T., & Schumann, K. (2018). Intellectual humility and openness to the opposing view. *Self and Identity, 17*(2), 139–162.
R Core Team (2017). *R: A language and environment for statistical computing.* Vienna, Austria: R Foundation for Statistical Computing2016.
Raven, J. C. (1938). *Raven's progressive matrices.* Western Psychological Services.
Roberts, R. C., & Wood, W. J. (2003). Humility and epistemic goods. In M. DePaul, & L. Zagzebski (Eds.). *Intellectual virtue: Perspectives from ethics and epistemology* (pp. 257–279). New York, NY: Oxford University Press.
Rodriguez, D., Hook, J. N., Farrell, J. E., Mosher, D. K., Zhang, H., Van Tongeren, D. R., ... Hill, P. C. (2017). Religious intellectual humility, attitude change, and closeness following religious disagreement. *The Journal of Positive Psychology,* 1–8.
Salerno, J. M., & Peter-Hagene, L. C. (2013). The interactive effect of anger and disgust on moral outrage and judgments. *Psychological Science, 24*(10), 2069–2078.
Salthouse, T. A., Fristoe, N., McGuthry, K. E., & Hambrick, D. Z. (1998). Relation of task switching to speed, age, and fluid intelligence. *Psychology and Aging, 13*(3), 445.
Samuelson, P. L., & Church, I. M. (2015). When cognition turns vicious: Heuristics and biases in light of virtue epistemology. *Philosophical Psychology, 28*(8), 1095–1113.
Samuelson, P. L., Jarvinen, M. J., Paulus, T. B., Church, I. M., Hardy, S. A., & Barrett, J. L. (2015). Implicit theories of intellectual virtues and vices: A focus on intellectual humility. *The Journal of Positive Psychology, 10*(5), 389–406.
Saunders, B., Milyavskaya, M., Etz, A., Randles, D., & Inzlicht, M. (2018, January 19). *Reported self-control is not meaningfully associated with inhibition-related executive function: A Bayesian analysis.* https://doi.org/10.17605/OSF.IO/BXFSU.
Schaie, K. W., Dutta, R., & Willis, S. L. (1991). Relationship between rigidity-flexibility and cognitive abilities in adulthood. *Psychology and Aging, 6*(3), 371.
Simmons, J. P., Nelson, L. D., & Simonsohn, U. A. (2012). A 21 word solution. Available at http://ssrn.com/abstract=2160588.
Spiller, S. A., Fitzsimons, G. J., Lynch, J. G., Jr., & McClelland, G. H. (2013). Spotlights, floodlights, and the magic number zero: Simple effects tests in moderated regression. *Journal of Marketing Research, 50*(2), 277–288.
Stanovich, K. E., & West, R. F. (1997). Reasoning independently of prior belief and individual differences in actively open-minded thinking. *Journal of Educational Psychology, 89*(2), 342.
Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology, 14*(2), 167–177.
Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. *Neuropsychology, 11*(1), 138.
Van der Linden, S., Leiserowitz, A., Rosenthal, S., & Maibach, E. (2017). Inoculating the public against misinformation about climate change. *Global Challenges, 1*(2).
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.
Van Tongeren, D. R., Stafford, J., Hook, J. N., Green, J. D., Davis, D. E., & Johnson, K. A. (2016). Humility attenuates negative attitudes and behaviors toward religious outgroup members. *The Journal of Positive Psychology, 11*(2), 199–208.
Whitcomb, D., Battaly, H., Baehr, J., & Howard-Snyder, D. (2015). Intellectual humility: Owning our limitations. *Philosophy and Phenomenological Research, 91*(1), 1–31.
Wright, J. C., Nadelhoffer, T., Perini, T., Langville, A., Echols, M., & Venezia, K. (2017). The psychological significance of humility. *The Journal of Positive Psychology, 12*(1), 3–12.
Zhang, H., Hook, J. N., Farrell, J. E., Mosher, D. K., Van Tongeren, D. R., & Davis, D. E. (2018). The effect of religious diversity on religious belonging and meaning: The role of intellectual humility. *Psychology of Religion and Spirituality, 10*(1), 72.
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, 115*, E4532–E4540 201708960.
Zmigrod, L., Rentfrow, P. J., & Robbins, T. W. (2019). *The partisan mind: Is extreme political partisanship related to cognitive inflexibility?* (under review).
Zmigrod, L., Rentfrow, P. J., Zmigrod, S., & Robbins, T. W. (2018). Cognitive flexibility and religious disbelief. *Psychological Research,* 1–11.