The Biological Roots of Complex Thinking: Are Heritable Attitudes More Complex?

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ABSTRACT Are highly heritable attitudes more or less complex than less heritable attitudes? Over 2,000 participant responses on topics varying in heritability were coded for overall *integrative complexity* and its 2 subcomponents (*dialectical complexity* and *elaborative complexity*). Across different heritability sets drawn from 2 separate prior twin research programs, the present results yielded a consistent pattern: Heritability was always significantly positively correlated with *integrative complexity*. Further analyses of the subcomponents suggested that the manner in which complexity was expressed differed by topic *type*: For societal topics, heritable attitudes were more likely to be expressed in dialectically complex terms, whereas for personally involving topics, heritable attitudes were more likely to be expressed in elaboratively complex terms. Most of these relationships remained significant even when controlling for measurements of attitude strength. The authors discuss the genetic roots of complex versus simple attitudes, implications for understanding attitude development more broadly, and the contribution of these results to previous work on both heritability and complexity.

Human thinking varies in its complexity. When psychologists consider where complex thinking comes from, we do not often think of things biological. Instead, a survey of the literature suggests we more frequently search for causes among the fertile fields of social/environmental influences (e.g., Conway, Schaller, Tweed, & Hallett,

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2001; Conway, Suedfeld, & Clements, 2003; Conway et al., 2008; Suedfeld & Bluck, 1988; Suedfeld & Rank, 1976) or chronic personality differences for which no necessary connection to biological influences is asserted (e.g., Coren & Suedfeld, 1995; Suedfeld, 2000; Suedfeld, Conway, & Eichhorn, 2001; Tetlock & Tyler, 1996; Thoemmes & Conway, 2007). Yet, like all human thinking, complex thinking has its roots in neurons firing in the brain—a set of biological events. And the structure of these biological things has its roots ultimately in the genetic makeup of the cells involved. In the present research, we examine one way in which this potential genetic influence on complex thinking can be understood.

When psychologists *do* think of genetic influences on humans, we more often think of the heritability of broad personality traits than the differential likelihood that specific attitudes will be inherited. Yet, as much research indicates, specific attitudes do in fact vary in their degree of heritability (Arvey, Bouchard, Segal, & Abraham, 1989; Eaves, Eysenck, & Martin, 1989; Keller, Bouchard, Arvey, Segal, & Dawis, 1992; Loehlin & Nichols, 1976; Martin et al., 1986; Olson, Vernon, Harris, & Jang, 2001; Perry, 1973; Scarr & Weinberg, 1981; Tesser, 1993; Waller, Kojetin, Bouchard, Lykken, & Tellegen, 1990), and this variability is important in understanding individual differences. In this article, we aim to demonstrate that topic-level attitude heritability is systematically related to the complexity of thinking about those topics.

Thus, the present research aims to combine these two oft-overlooked areas of research by asking the following question: Are heritable attitudes more complex? In so doing, we are not trying to explain heritability per se but rather are attempting to show what consequences it has for real-life attitudes.

Integrative Complexity, Elaborative Complexity, and Dialectical Complexity

What is complex thinking? We focus here on the most-used and widely validated measurement of complex thinking: integrative complexity. Integrative complexity assesses the complexity of spoken or written communications according to their basic structure (see, e.g., Suedfeld & Bluck, 1988; Suedfeld & Leighton, 2002; Suedfeld & Piedrahita, 1984). Passages are coded and assigned a score between 1 and 7 based on the level of differentiation (i.e., the extent to which differing dimensions are used to describe a given topic, scores 1–3) and, if more than one dimension is present, integration (i.e., the merging of these multiple dimensions into a larger hierarchical structure, scores 4–7; see Baker-Brown et al., 1992).

In assigning complexity scores, the particular position argued for by the speaker/writer is irrelevant; the score is based on the *structure* of the passage rather than its substance or meaning. As such, this construct is able to capture the underlying mechanisms of the complexity of thought on a broad level regardless of variables that may influence the cognitive strategies used in formulating the passages. Due to this breadth, two passages that describe the same topic in very different ways can receive the same integrative complexity score. Although this feature is in many ways a strength of the construct, it also limits theory building because knowing *why* a particular passage is complex is often difficult. In response to this problem, Conway et al. (2008) developed two subordinate constructs under the rubric of the multiple complexity model. The model, designed as a supplement to and not as a replacement for the integrative complexity construct, considers the different routes by which complex thinking arises. In particular, it considers whether complexity assigned through integrative complexity coding arose in an elaborative complexity form, a dialectical complexity form, or both.

Elaborative complexity is achieved when a topic is described using two or more differentiated points supporting *either* a positive *or* a negative dominant theme, but not both. Consider the statement "Roller-coasters are not fun. I feel fearfully anxious when I am in line for them, and once I get off I have a headache for hours." Both of these differentiated, negative elements are used to support the negative argument that roller coasters are not fun. In contrast, *dialectical complexity* is achieved when *both* negative *and* positive aspects of the same topic are differentiated, giving validity to each side. Consider the statement "I both dislike and like roller-coasters. I get very scared when I'm in line, but I always laugh and feel good while I'm on them." Both a negative element and a positive element are used to describe the topic. (A passage may further contain both elaborative and dialectical complexity.)

The multiple complexity model is incorporated into the integrative complexity construct, and the passages are coded and scored on the same 1–7 scale. A passage is first scored for overall integrative complexity; then trained coders assess how much of that score is due to elaborative complexity or dialectical complexity (see Conway et al., 2008, for details). Therefore, all passages coded under the multiple complexity model receive three scores: one for overall integrative complexity and one for each subcomponent (elaborative, dialectical).

Heritability and Complexity: Two Perspectives

So how might the heritability of an attitude be related to the complexity of its representation in the average mind? We do not offer a specific hypothesis here; rather, we discuss two alternative perspectives that we will subsequently test.

Before discussing these views, it is worth noting that both of these perspectives assume that heritability—or the variance attributable to genetic differences—plays some *causal* role in the complexity of thinking. Although environmental circumstances can influence gene structure, both models discussed below rest on the idea that the heritability of a given attitude *preceded*—and therefore was not influenced by—the development of its structural representation in the brain (for a similar argument relevant to heritability in correlational designs, see Tesser, 1993).

Heritability and "Belief Maintenance"

One perspective on how heritability might be related to attitude complexity can be labeled a "belief maintenance" view (e.g., see Conway et al., 2008). This perspective rests on the fact that highly heritable attitudes are stronger (Olson et al., 2001; Tesser, 1993) and less open to immediate social influence (Tesser, 1993). Work in numerous domains has shown that humans are motivated to protect cherished beliefs and to psychologically maintain strong attitudes (see Conway et al., 2008, for a review).

The desire for belief maintenance invoked by strong attitudes should have different effects on the two subcomponents of complexity distinguished by Conway et al. (2008). In particular, more strongly held attitudes should produce less dialectical complexity (as people refuse to consider alternative viewpoints) but more elaborative complexity (as people defend their cherished viewpoint), resulting in relatively detailed knowledge that uniformly supports the preferred attitude position. Previous research has shown that, in fact, multiple markers of attitude strength are negatively related to dialectical complexity but positively related to elaborative complexity (Conway et al., 2008).

Thus, to the degree that high heritability operates on complexity by increasing the strength of an attitude, a pattern consistent with this belief maintenance hypothesis might be expected. Such a pattern would involve (1) little or no correlation between heritability and overall integrative complexity, (2) a positive correlation between heritability and elaborative complexity, and (3) a negative correlation between heritability and dialectical complexity. Finally, this belief maintenance view suggests that the opposing relationships for the subcomponents (2 and 3 above) ought to be mediated by measurements of attitude strength.

Heritability and "Enduring Biological Substrate"

On the other hand, a different perspective suggests that the relationship between heritability and complexity ought to be more consistently positive across all types of complexity. Extending the theory of Tesser (1993), it may be that highly heritable attitudes are more likely to have (in Tesser's terms) "enduring biological substrate" devoted to them in the brain.[1] This physical space in the brain may be more likely, on average, to produce more complex representations. This reasoning is based on probabilistic logic: Although biological substrate may be devoted to both simple and complex representations, complex representations, almost by definition, require more physical space in the brain than simple ones. For example, considering a typical semantic network view (e.g., Tyler et al., 2003), it requires more neuronal connections to maintain the opinion "roller-coasters are both negatively frightening and fun" than to maintain the simpler opinion "roller-coasters are fun" because the first requires more semantic nodes. Thus, probabilistically speaking, it is more likely that highly heritable attitudes would be represented more complexly because they are more likely to have the biological material devoted to them that forms the backbone of complex attitudes.

1. Throughout, we focus on the "amount" of biological substrate in the brain, whereas Tesser (1993) seemed more focused on the "enduring" and unchanging nature of it. We do not wish to misrepresent what Tesser argued, but rather to use his ideas as a jumping-off point. Tesser did not seem to argue directly, as we do, that high heritability produces *more* material in the brain, but rather that the material devoted to it was of a different *quality*. Nonetheless, we think that our account is not inconsistent with his and plausibly accounts for our results.

Although we are aware of no direct evidence for heritability increasing complexity, some indirect evidence suggests that higher heritability could be inexorably linked with more complex processing. In particular, from the literature on cognitive testing, more complex *g*-loaded tests are more highly heritable than less complex tests (see Jensen, 1998). Though this does not necessarily mean that people will have a more complex representation of highly heritable attitudes, it is loosely consistent with the idea that high heritability is associated with more complex processing at some fundamental level.

This substrate-complexity relation could take different guises. For example, assuming strong attitudes have more enduring substrate devoted to them (see Tesser, 1993, for a discussion), some of the increase might be in elaborative complexity as people strive to defend cherished attitudes (and thus, in a sense, be consistent with the belief maintenance view presented above, an issue we return to in the discussion). On the other hand, there is no clear reason why enduring biological substrate would be devoted solely to elaborative complexity. Indeed, the additional substrate associated with higher heritability might also make people more prone to search out answers to questions more fully, thus being willing to take in all sides of a topic. As a result, increased heritability might be associated with an increase in dialectical complexity as well.

Thus, like the belief maintenance model, the biological substrate model suggests that heritability will be positively related to elaborative complexity. The biological substrate perspective offers diverging predictions, however, pertaining to overall integrative complexity and dialectical complexity. In particular, in contrast to the belief maintenance view, the substrate model suggests that both of these correlations ought to be positive.

Heritability and Topic Type

A final difference between the two approaches to the heritability-complexity relationship pertains to the substantive domain of the focal attitude. It is possible that certain attitudes (independent of heritability) may be more likely to yield one type of complexity than the other. This might take many forms. For example, if average U.S. college participants were asked to describe their opinion of the "Nazi party," little dialectical complexity would ensue because most college students have almost entirely negative ideas about the Nazi party. Thus, any complexity they would exhibit in this instance would be elaborative, and, in this and other ways, certain attitude topics or domains may "pull" for one type of complexity more than another.

This point has theoretical implications for our two models. If the belief maintenance model is valid, topics more likely to exhibit elaborative complexity will have a positive relationship between heritability and elaborative complexity and no relationship between heritability and dialectical complexity. On the other hand, topics that "pull" for dialectical complexity will have a negative relationship between heritability and dialectical complexity and no relationship for elaborative complexity.

If the biological substrate model is valid, *both* dialectical and elaborative complexity are expected to yield generally positive relations with heritability, when such relations are possible. Consequently, topics that pull for elaborative complexity will have a positive relation between heritability and elaborative complexity and no relation between heritability and dialectical complexity. Topics that pull for dialectical complexity will have a positive relation between heritability and dialectical complexity and no relation for elaborative complexity.

A simple way to conceptualize this difference is to note that, whereas both models predict that the relation between heritability and elaborative complexity will sometimes be near zero and sometimes be positive, the belief maintenance model predicts that the relation between heritability and dialectical complexity will tend to move between zero and negative values, whereas the biological substrate model predicts that the relation between heritability and dialectical complexity will tend to move between zero and positive values. Thus, to the degree that some topic types elicit positive relations between heritability and dialectical complexity, the biological substrate model will be supported.

To examine this question, we draw on past factor analyses (when enough information is available to do so; Olson et al., 2001) and divide attitude topics in the present research into different "types."

METHOD

Overview and Participants

Over a 2-year span, 1,801 undergraduate participants at the University of Montana completed open-ended questions pertaining to an array of attitudes in exchange for course credit, usually in large sessions exceeding 100 persons. These questions were later coded by trained scorers for their structural complexity. Question stems were chosen because they had been previously assessed for their heritability in one of two prior, well-known heritability research programs (Eaves et al., 1989; Martin et al., 1986; Olson et al., 2001). We chose these specific heritability research programs because they are the largest and most recent of the studies assessing attitude heritability and thus have been used most extensively by other researchers (e.g., Bourgeois, 2002; Crelia & Tesser, 1996; Tesser, 1993; Tesser & Crelia, 1994).

For the most part, each participant completed an attitude item from only one of the two study sets (Eaves et al., 1989; Martin et al., 1986; Olson et al., 2001). However, a subset of 423 participants completed an item from both heritability sets. We essentially treated these overlapping responses from each participant as independent. Although it is conceptually possible that (for the subsample of 423 only) participants' responses on the first set influenced their responses on the second set, we statistically controlled for that possibility by computing all primary analyses on the sample of 423 for each set while statistically controlling for all variables (complexity, heritability) from the other set. These analyses revealed no change when the other topic set was accounted for: participants showed a pattern of results identical, both descriptively and inferentially, to the same analyses without controlling for variables from the other topic set. This demonstrates the validity of treating participants' responses to those attitude items independently (see Conway et al., 2008, for a similar treatment).

Participant as Unit of Analysis

Our strategy was straightforward: Using the participant response as the unit of analysis, we correlated the heritability of the attitude the participant wrote about with markers of the structural complexity of the attitude (as coded by our lab). This approach yielded 2,237 responses to analyze.[2] We opted to use the participant as the unit of analysis for four reasons. (1) We were following the principle outlined by Cohen (1990) that, unless there is a compelling statistical reason to do otherwise, one should use the unit of analysis that provides the highest available N and thus avoids unnecessarily lowering power. In this case, no statistical assumptions were violated by using the participant as the unit of analysis (e.g., the assumption of independence was not violated because partici-

2. A portion of the participants (760) produced data that were presented in previous work on complexity (Conway et al., 2008); however, that work pertained to attitude strength and not to heritability. The full data set is presented for the first time here, and analyses on heritability using this data set are also presented here for the first time. Thus, unless otherwise noted in the text, all the work presented in this article is novel.

pants' responses on each question were independent from all fellow participants). (2) We are primarily interested in demonstrating the consequences of heritability on individual attitudes; thus, it makes sense to use individuals as the unit of analysis. (3) In essence, this strategy is (both statistically and methodologically) no different than the common technique of assigning "conditions" based on different categories of topic stems or different wording of scenarios (e.g., Bourgeois, 2002; Conway & Schaller, 2005; Cullum & Harton, 2007; Tesser, 1993), or a strategy that uses a repeated macrolevel variable to predict something at a microlevel (e.g., Conway, Clements, & Tweed, 2006). (4) Prior work applying the Martin et al. (1986) and Eaves et al. (1989) heritability figures have relied, at least in part, on a similar strategy that employs assigning the participant as the unit of analysis (Bourgeois, 2002; Tesser, 1993). For these reasons, we opted to use the participant as the unit of analysis. However, for the interested reader, we also provide summaries of item-level analyses in a footnote. Although predictably inferentially weaker, these item-level analyses descriptively corroborated the individual-level results presented in the main narrative.

Attitude Items and Estimates of Heritability

As in much previous research on attitude heritability (e.g., Bourgeois, 2002; Crelia & Tesser, 1996; Tesser, 1993; Tesser & Crelia, 1994), we did not conduct a twins study; rather, to reflect the heritability of attitudes, we used previous researchers' heritability coefficients for various attitude items (Eaves et al., 1989; Martin et al., 1986; Olson et al., 2001; Perry, 1973).

A heritability coefficient is not a direct measurement of the amount of a particular attitude that is "caused" by genetic forces; rather, it is more properly a measurement of "the amount of variation on the characteristic in the sample [that] is attributable to genetic differences" (Olson et al., 2001, p. 846). For example, some traits that are highly genetically influenced—like the fact that humans have two legs—will have low heritability coefficients because the highly shared genetic nature of the trait means there is little variability on the trait to begin with (see Olson et al., 2001). Although clearly containing multiple limitations, the heritability coefficient is nonetheless the most widely used marker for understanding genetic variation. Rather than discuss those limitations at length here, we refer the reader to excellent discussions from other sources (see Olson et al., 2001; Tesser, 1993).

Using standard heritability methods with monozygotic and dizygotic twins, prior researchers calculated the heritability coefficients of various attitude items. For our purposes, we divided those items into two different heritability sets: Heritability Set 1 consisted of items primarily from Martin et al. (1986) and Eaves et al. (1989; for both studies, we accessed these items from Tesser, 1993) and was further supplemented by Perry

(1973). Heritability Set 2 consisted of items from Olson et al. (2001). The average heritability coefficients for the two sets were virtually identical (Heritability Set 1 = .32; Heritability Set 2 = .33). For Heritability Set 2, Olson et al. (2001) also provided separate heritability estimates for categories of items that were grouped according to a factor analysis (described below).

Regardless of the heritability set from which an item originated, participants always received the same directions: "Please write a paragraph expressing your opinion on the following topic. To do this, we want you to write a paragraph about whether your attitude is positive or negative (or a combination) towards the following topic and explain why that is so." This was always followed by a particular statement or phrase (e.g., "abortion on demand"). See Table 1 for a listing of all items, their sources, and their topic type classification used in the present work.

Participants were randomly assigned to the particular attitude stem. This design helps rule out, or at least make improbable, any confounds based on personality traits or abilities (e.g., cognitive abilities). A personality- or ability-related trait would only matter to our results if people who were randomly assigned to highly heritable attitudes happened, by chance, to have (for example) higher cognitive abilities. As random assignment of attitudes makes this as improbable as in any study involving random assignment of conditions, such traits are unlikely to account for our results.

Heritability Set 1

The first topic set, drawn from Martin et al. (1986), Eaves et al. (1989), and Perry (1973),[3] consisted of 12 items, most of which had been originally designed to be relevant to political conservatism. From the three sources' available possible items, we chose parallel sets of items that were roughly matched by content domain. Sometimes the matched items were similar in terms of documented heritability (e.g., the death penalty), and sometimes the matched items had widely different levels of heritability (e.g., sex/marriage). In particular, we had two items pertaining to the death penalty, two pertaining to sex/marriage, two pertaining to religion, two pertaining to legal substances (smoking, alcohol), and four pertaining to broader societal issues (censorship, socialism, coeducation, and immigration policy). Most of these matched comparisons yielded results

3. The 2 Perry items were actually based on the average score for scales of 20 items each, starting with either "Drinking alcohol . . ." or "Cigarette smoking . . ." and then describing some negative or positive potential consequences. The stem we used was the main stem common across all 20 items (Perry did not give heritability estimates for the 20 items separately).

Table 1
Topic Stems Used in Present Research

Item	H Set	H Source	Olson Factor (Summary Classification)	H^2	N	Integrative Complexity	Dialectical Complexity	Elaborative Complexity
Men and women have the right to find whether they are sexually suited before marriage.	1	Eaves et al. (1989)	N/A	.57	77	1.81	1.49	1.40
Sex relations except in marriage are always wrong.	1	Eaves et al. (1989)	N/A	.04	134	2.27	1.93	1.53
Death penalty	1	Martin et al. (1986)	N/A	.51	141	2.13	1.72	1.60
The death penalty is barbaric and should continue to be abolished.	1	Eaves et al. (1989)	N/A	.56	74	2.07	1.61	1.62
The average person can live a good enough life without religion.	1	Eaves et al. (1989)	N/A	.55	214	2.09	1.72	1.49
Bible truth	1	Martin et al. (1986)	N/A	.25	229	1.98	1.75	1.37
Drinking alcohol	1	Perry (1973)	N/A	.51	83	2.47	2.26	1.57
Smoking cigarettes	1	Perry (1973)	N/A	.12	79	2.32	1.46	1.94
Censorship	1	Martin et al. (1986)	N/A	.41	138	2.16	1.88	1.42

(Continued)

Table 1 (Cont.)

Item	H Set	H Source	Olson Factor (Summary Classification)	H^2	N	Integrative Complexity	Dialectical Complexity	Elaborative Complexity
Socialism	1	Martin et al. (1986)	N/A	.26	99	2.02	1.73	1.40
Refugees should be left to fend for themselves.	1	Eaves et al. (1989)	N/A	.11	119	1.79	1.49	1.36
Coeducation	1	Martin et al. (1986)	N/A	.07	119	2.00	1.31	1.78
Doing crossword puzzles	2	Olson et al. (2001)	Sweets and games (personal)	.45	7	2.04	1.50	1.57
Sweets	2	Olson et al. (2001)	Sweets and games (personal)	.22	41	2.07	1.80	1.50
Open-door immigration	2	Olson et al. (2001)	Equality (societal)	.46	10	2.18	1.72	1.50
Doing athletic activities	2	Olson et al. (2001)	Athletics (personal)	.44	30	2.28	1.41	2.01
Voluntary euthanasia	2	Olson et al. (2001)	Preservation of life (societal)	.44	16	2.16	1.82	1.54
Smoking	2	Olson et al. (2001)	Sensory (personal)	.31	15	2.67	2.08	1.80
Being the center of attention	2	Olson et al. (2001)	Leadership (personal)	.28	14	2.52	2.13	1.69
Separate roles for men and women	2	Olson et al. (2001)	Equality (societal)	.00	57	1.98	1.67	1.45

(Continued)

Table 1 (Cont.)

Item	H Set	H Source	Olson Factor (Summary Classification)	H^2	*N*	Integrative Complexity	Dialectical Complexity	Elaborative Complexity
Education	2	Olson et al. (2001)	Intellectual pursuits (personal)	.32	15	2.24	1.68	1.75
Making racial discrimination illegal	2	Olson et al. (2001)	Equality (societal)	.34	19	2.31	2.01	1.48
Getting along well with other people	2	Olson et al. (2001)	Outward appearance (personal)	.28	17	2.32	1.91	1.60
Capitalism	2	Olson et al. (2001)	Intellectual pursuits (personal)	.39	14	1.95	1.72	1.43
Playing organized sports	2	Olson et al. (2001)	Athletics (personal)	.52	39	2.66	1.60	2.35
Big parties	2	Olson et al. (2001)	Sensory (personal)	.32	15	2.47	2.28	1.55
Playing chess	2	Olson et al. (2001)	Intellectual pursuits (personal)	.38	14	2.18	1.72	1.56
Abortion on demand	2	Olson et al. (2001)	Preservation of life (societal)	.54	16	2.31	2.04	1.51
Public speaking	2	Olson et al. (2001)	Leadership (personal)	.20	16	2.38	2.06	1.66
Playing bingo	2	Olson et al. (2001)	Sweets and games (personal)	.00	53	1.93	1.58	1.51
Wearing clothes that draw attention	2	Olson et al. (2001)	Outward appearance (personal)	.24	21	2.25	1.78	1.60

(Continued)

Table 1 (Cont.)

Item	H Set	H Source	Olson Factor (Summary Classification)	H^2	*N*	Integrative Complexity	Dialectical Complexity	Elaborative Complexity
Easy access to birth control	2	Olson et al. (2001)	Preservation of life (societal)	.00	50	1.99	1.50	1.60
Exercising	2	Olson et al. (2001)	Athletics (personal)	.36	16	2.39	1.60	1.98
Organized religion	2	Olson et al. (2001)	Preservation of life (societal)	.45	39	2.35	2.01	1.71
Being the leader of groups	2	Olson et al. (2001)	Leadership (personal)	.41	17	2.38	1.94	1.60
Reading books	2	Olson et al. (2001)	Intellectual pursuits (personal)	.57	17	2.39	1.41	2.07
Castration as a punishment for sex crimes	2	Olson et al. (2001)	Criminal punishment (societal)	.17	15	2.28	1.79	1.59
Being assertive	2	Olson et al. (2001)	Leadership (personal)	.00	32	2.12	1.57	1.74
Roller-coaster rides	2	Olson et al. (2001)	Sensory (personal)	.52	52	2.07	1.68	1.67
Loud music	2	Olson et al. (2001)	Sensory (personal)	.11	16	2.33	2.27	1.18

Note. H Set = heritability set as referred to in the text; Olson Factor = factor according to Olson et al. (2001) factor analysis (our summary classification in parentheses not drawn directly from Olson et al.); H^2 = heritability of item as assigned by previous researchers.

descriptively consistent with the overall pattern presented below (e.g., demonstrating higher complexity for a higher-heritability item than a matched low-heritability counterpart; although the sex/marriage comparison was an exception). However, we chose to focus on analyses on the whole set of data for which greater power was available. The interested reader can see all results of the matched pairs in Table 1.

Overall, 1,502 participants completed one of the Set 1 items over the course of three separate terms. (All analyses were performed within term as well; the results look virtually identical, both descriptively and inferentially, within term as for the whole sample combined.) All participants completed their surveys in large mass-testing sections, with the exception of 48 participants who completed their surveys in smaller sessions (e.g., 1–6 people).

Heritability Set 2

Heritability Set 2 consisted of 30 stimulus items taken from Olson et al. (2001). There were 735 participants randomly assigned to complete one of the 30 items over the course of three separate terms. Heritability Set 2 allowed for more specific analyses than Set 1 for two reasons.

(1) It contained a much broader selection of attitude topics, which included topics similar to Heritability Set 1 (e.g., "voluntary euthanasia," "death penalty for murder," "capitalism"), but also a separate array of topics relevant to other domains, such as how they felt about various activities (e.g., "playing chess," "doing crossword puzzles") and personal traits (e.g., "looking my best at all times," "getting along well with other people," "being the leader of groups").

(2) Olson et al. (2001) provided a set of empirically justified factors and accompanying factor heritability scores. The factors were as follows: equality (e.g., racism), preservation of life (e.g., abortion), criminal punishment (e.g., castration for sex crimes), athletics (e.g., exercising), sensory (e.g., big parties), intellectual pursuits (e.g., playing chess), leadership (e.g., being self-assertive), outward appearance (e.g., looking my best at all times), and sweets and games (e.g., crossword puzzles).

Note that the first three of these (equality, preservation of life, and criminal punishment) contain items very similar to those in Heritability Set 1, whereas most of the other six factors contain items very different from Heritability Set 1. On this basis, we further grouped the first three factors into a larger category we refer to as *societal* items and the last six factors into a larger category called *personal* items. Consistent with this categorical grouping, the personal items were in fact judged by participants to be significantly more personally involving. However, though empirically justified, in the present work we use this distinction primarily as an important rhetorical device: we want to show that, although on the surface Heritability Sets 1 and

2 show seemingly different patterns with respect to the subcomponents of dialectical and elaborative complexity (they show an identical pattern with respect to overall integrative complexity, as will be seen below), this apparent discrepancy is attributable to the different types of items in each set. When item factors are taken into account, the two sets actually show very similar patterns. Table 1 presents the classification of each item into Olson's factors, as well as into our larger categories.

Resolving set similarities

Our topic stems were identical to those used by the original researchers who computed heritability coefficients. Although stems from different topic sets were occasionally very similar (e.g., "death penalty" in Heritability Set 1, "death penalty for murder" in Heritability Set 2), we opted to use the heritability coefficient for that specific item from the heritability study within which it was computed.

Heritability coefficients

In our correlational analyses, when participants wrote about a particular item X, we treated the heritability coefficient calculated by previous researchers as that item's "heritability" (using the participant as the unit of analysis, as described earlier). For Heritability Set 2, we further did a separate analysis that used the *factor* heritability score for the item participants wrote about (as opposed to the specific individual item heritability). So, for this analysis, if a participant wrote about one of the items in Olson and colleagues' (2001) "sensory" factor, we entered the heritability for that factor, as opposed to the heritability for that item. Because we control for the item heritability score (reported below), this strategy essentially provides an independent test of the basic results of the article.

Complexity Scoring

All open-ended responses were scored for overall *integrative complexity, dialectical complexity,* and *elaborative complexity* by seven trained coders who had previously achieved a reliability level for integrative complexity of at least .85 with an expert coder and had subsequently received extensive training in coding the two subcomponents (see Baker-Brown et al., 1992, for procedural details of integrative complexity scoring and Conway et al., 2008, for discussion of elaborative complexity and dialectical complexity scoring). Coders were blind to the heritability of the items they were coding. The average integrative complexity scores were 2.1 (for Set 1) and 2.2 (for Set 2). While these scores may seem low on a 1–7 scale, they are actually very typical for the integrative complexity construct (integrative complexity tends to be skewed toward the lower end of the scale). For example, a recent study of 40 U.S. presidents' state of the union speeches had an overall integrative complexity mean of 1.8 (Thoemmes & Conway, 2007).

Every coder did not score every response across the entire 2,237 responses. The majority of responses were coded by four to five coders in "blocks" (usually comprising a particular academic term) of around 500 responses each. For each block, every coder of that block scored all participants (and hence all topics) for that block. Thus, summary scores provided below are the average of four to five coders for each participant. Reliability on each of the different blocks was satisfactory for each complexity variable, regardless of the particular set of coders. In particular, integrative complexity alphas range from .79 to .81; $M = .80$. Dialectical complexity alphas range from .81 to .89; $M = .86$. Elaborative complexity alphas range from .73 to .80; $M = .76$.

Although within-block analyses yielded a pattern similar to that reported below, we nonetheless account directly for the potential differences among blocks of coders by standardizing the complexity scores within block (essentially, within term). All analyses are thus reported below using these standardized scores. The coders' scores for each complexity type were averaged to create three composite scores: *integrative complexity, dialectical complexity*, and *elaborative complexity*. (In Table 1, we report the raw scores to facilitate across-study comparison. Analyses on the raw scores yielded a pattern of results nearly identical to that reported using the more precise standardized scores.)

Mediating Variables

We also had subsets of participants complete some items relevant to constructs that we thought might mediate the heritability-complexity relation because they were relevant to belief maintenance (such as attitude strength measures), cognitive/biological space that might be devoted to the attitude (such as cognitive experience or cognitive effort), or both. In particular, after completing the opinion question, some participants were asked to rate that topic stem on several standard 7-point rating scales relevant to psychological importance, personal involvement, the amount of effort they put into writing their opinion, their confidence in their opinion, and the amount of prior cognitive experience they had thinking about the topic (see, e.g., Conway et al., 2008). For Set 1, 425 participants completed questions relevant to each dimension. For Set 2, all participants completed questions relevant to topic importance, but only a subset ($n = 428$) completed items relevant to the other dimensions.

Regardless of heritability set, two questions relevant to each of the above dimensions were averaged to create composite scores for topic *importance* (average alpha = .81), *personal involvement* (average alpha = .83), *confidence* (average alpha = .66), *prior cognitive experience* (average alpha = .87), and *cognitive effort* (average alpha = .80). When multiple terms/samples were involved, standardized scores were first computed within term or within sample.

RESULTS

Primary Analyses

Item heritability for both sets

As Table 2 indicates, for both heritability sets, a positive and statistically significant correlation emerged between attitude heritability and the overall integrative complexity measure. Interestingly, additional analyses of the two subcomponents suggested that the specific *marker* of integratively complex thinking varied by set. For Heritability Set 1, a significant positive correlation emerged between attitude heritability and dialectical complexity, whereas no correlation emerged between heritability and elaborative complexity. For Heritability Set 2—which

Table 2
The Relations Between Item Heritability and Complexity Measures by Heritability Set and Topic Type (Standardized Within Term)

	IC	Dialectical	Elaborative
Heritability Set 1 (*n* = 1,502)	.06*	.11***	– .03
Heritability Set 2 (*n* = 735)	.12***	.00	.16***
Set 2: Societal only (*n* = 271)	.08	.09^	.04
Preservation of life (*n* = 121)	.15^	.23*	.02
Equality (*n* = 86)	.03	– .03	.05
Criminal punishment (*n* = 50)	– .01	.08	– .07
Set 2: Personal only (*n* = 464)	.14***	– .08^	.23***
Athletics (*n* = 85)	.29**	.15	.20^
Leadership (*n* = 79)	.03	.07	– .06
Sensory (*n* = 98)	– .11	– .23*	.23*
Intellectual pursuits (*n* = 60)	.17	– .23	.29*
Outward appearance (*n* = 55)	.22^	.40**	– .10
Sweets and games (*n* = 85)	.03	.03	.02

Note. All tests two-tailed. IC = integrative complexity; Dialectical = dialectical complexity; Elaborative = elaborative complexity.
^$p < .15$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 3
The Relations Between *Factor* Heritability and Complexity Measures by Topic Type (Standardized Within Term) for Heritability Set 2

	IC	Dialectical	Elaborative
Total Heritability Set 2 ($n = 735$)	.10**	.05^	.07*
Societal only ($n = 271$)	.07	.07	.04
Personal only ($n = 464$)	.21**	.04	.18**

Note. All tests two-tailed. IC = integrative complexity; Dialectical = dialectical complexity; Elaborative = elaborative complexity.
^$p < .15$. *$p < .05$. **$p < .01$.

contained a broader array of topics—a significant positive correlation instead emerged between attitude heritability and elaborative complexity, whereas no correlation emerged for dialectical complexity.

Factor heritability for Set 2

For Heritability Set 2, Olson et al. (2001) also performed a factor analysis on the 30 heritability items and subsequently provided heritability figures for the nine resulting factors. In a separate analysis, we entered these scores for each participant into a "factor heritability" variable. To account for overlap between this analysis and the item heritability analysis, we controlled for item heritability. Both zero-order and partial correlations (controlling for item heritability) showed an identical pattern of descriptive and inferential statistics; for simplicity, we focus here on the zero-order correlations.

These results, though statistically independent of the item heritability results, show a very similar pattern (see Table 3): factor heritability was significantly positively related to overall integrative complexity, significantly positively related to elaborative complexity, and positively (but not quite significantly) related to dialectical complexity.

It is worth emphasizing that, regardless of heritability set or type of heritability score (factor vs. item), the overall trend was toward heritability being associated with *greater* complexity. This pattern is highly consistent with a biological substrate view. There were no significant negative correlations between the subcomponents and heritability, and the main integrative complexity construct, which captures *overall* complexity, demonstrated this significant positive relation in both sets (and for both the item and factor heritability scores in Set 2). Thus, although we explore potential moderators of how this complexity was *expressed* below, it should be kept in mind that higher heritability was always associated with increases in at least one form of complexity. In these additional analyses, we are in essence asking the following question: given that high heritability increased complexity, what factors changed *how* that complexity got expressed?

Moderating Mechanisms for Elaborative Versus Dialectical Complexity

First, to understand how our two broad topic types for Heritability Set 2 differed, we computed *t* tests comparing *societal* versus *personal topics* on the various 7-point rating scale attributes. These analyses revealed that participants viewed the societal topics (compared to the personal topics) as more important (*importance*), $p < .01$. Further, consistent with the conceptualization offered here that our personal topics are in fact more directly personal to participants than societal topics, they reported that they had far less personal involvement with societal topics than with personal topics, $p < .001$. Finally, to assess whether the sets differed in the likelihood of "pulling" for dialectical versus elaborative, we ran a 2 (complexity type: dialectical vs. elaborative) × 2 (topic type: societal vs. personal) mixed model ANOVA. This analysis revealed that societal topics showed more dialectical than elaborative complexity, whereas personal topics showed more elaborative than dialectical complexity (interaction $F[1,733] = 7.07$, $p = .008$).[4]

How do these different topic types affect the heritability-complexity relationship? As Tables 2 and 3 reveal, when analyzing only societal items from Heritability Set 2, a pattern of correlations emerged that paralleled Heritability Set 1: A weak positive correlation emerged between attitude heritability and dialectical complexity, whereas less correlation emerged for elaborative complexity. A very different pattern was obtained, however, when looking at only personal topics: A significant positive correlation emerged between

4. Importantly, Heritability Set 1 showed a pattern almost identical to the societal topics from Set 2, with much higher dialectical than elaborative scores, $p < .001$. This corroborates our general account that attitude domains that "pull" for dialectical complexity lead to more positive heritability-dialectical complexity correlations.

attitude heritability and elaborative complexity, whereas a negative but nonsignificant correlation emerged for dialectical complexity.

Thus, when topics similar to those used in Heritability Set 1 were analyzed exclusively in Heritability Set 2, the two sets revealed a nearly identical pattern of results, at least descriptively. These parallel patterns suggest that the differences between the two heritability sets (in terms of complexity subcomponents' relations to heritability) were directly accounted for by the differences in topic *type*.[5,6]

We assessed the moderating impact of topic type more directly for Heritability Set 2 via standard procedures for testing moderators using regression techniques (e.g., Conway & Schaller, 2005). This entailed (1) converting both the heritability variable and the topic type variable (personal vs. societal, dummy-coded originally as 1 and 2) to z scores, (2) creating a heritability $\times$ topic type interaction term, and (3) running a linear regression entering heritability, topic type, and the interaction term as independent variables. For the dependent variable, to capture the degree that persons differentially expressed the two forms of complexity in their explanations of their attitudes, we created a difference score by subtracting (using z scores for each variable) dialectical complexity from elaborative complexity. Scores above zero

5. Although our primary focus was predicting *individual* attitudes from heritability coefficients, we also conducted topic-level analyses. These analyses yielded a pattern of results that—although (unsurprisingly) inferentially weaker due to a dramatically smaller n—was descriptively similar to that for the person-level analyses. For Heritability Set 1, heritability was positively correlated with both integrative complexity ($r[12] = .14$, $p = .664$) and dialectical complexity ($r[12] = .36$, $p = .251$) but not elaborative complexity ($r[12] = -.18$, $p = .576$). For Heritability Set 2, heritability was positively correlated with both integrative complexity ($r[30] = .17$, $p = .360$) and elaborative complexity ($r[30] = .36$, $p = .050$) but not dialectical complexity ($r[30] = -.18$, $p = .352$). Dividing Heritability Set 2 into societal and personal topics similarly yielded results identical to the person-level analyses. For societal topics, heritability was positively correlated with dialectical ($r[12] = .23$, $p = .466$) but not elaborative complexity ($r[12] = .00$, $p > .99$). For personal topics, heritability was positively correlated with elaborative ($r[18] = .53$, $p = .024$) but not dialectical complexity ($r[12] = -.37$, $p = .135$).

6. Although most of the topics from Set 1 were clearly in the societal domains of Olson and colleagues' (2001) factor analyses, a few were not. To account for this, we did a separate analysis looking at topic type using a direct comparison of items from the Olson study, categorized as either "similar to Set 1" or "not similar." These results were descriptively and inferentially identical to those reported in the text on topic type, including the fact that topic type moderated the relation between heritability and complexity type, heritability $\times$ topic type $\beta = .13$, $p < .001$.

thus indicate a tendency to use more elaborative complexity, whereas scores below zero indicate a tendency to use more dialectical complexity. This regression analysis allowed us to test directly whether the pattern observed above—suggesting that topic type changed whether heritability was related to elaborative or dialectical complexity—was statistically significant. The resulting regression did, indeed, suggest that topic type moderated the relation between heritability and complexity type, heritability × topic type $\beta = .13$, $p < .001$.

As can be seen in Table 3, the factor heritability scores from Set 2 showed a pattern that was similar to that for the item heritability scores, except that dialectical complexity was more consistently positively related to heritability. This exception weakened the effect of the interaction between topic type (societal, personal) and heritability on the subcomponent difference score: although in the same direction, the interaction term approached, but did not attain, statistical significance ($\beta = .07$, $p = .072$).

Taken as a whole, however, this set of moderation results is more consistent with a view based on enduring biological substrate than on belief maintenance because it statistically captures the pattern that heritability was sometimes positively, and never negatively, correlated with dialectical complexity.[7]

Mediating Mechanisms

Do any of the measured attributes account directly for any of the relations between heritability and complexity reported in Tables 2 and 3? To test for mediation, we first computed zero-order correlations between heritability and the three complexity markers for the specific subsets of participants who completed the mediational measures (see columns 1, 3, and 5 of Table 4 for these correlations). We then computed zero-order correlations between heritability and each mediator separately (column 1 of Table 5). We subsequently com-

7. If the belief maintenance model were correct, no interaction between topic type and heritability should have emerged on the difference score. The belief maintenance view predicts that dialectical complexity will have a more negative relationship to heritability than elaborative complexity across all topics, whereas the biological substrate model suggests that, because sometimes dialectical complexity has a more positive relationship to heritability than elaborative complexity, the two will "switch places" in terms of their relative positivity to heritability. It is this exact pattern that emerged and is validated by the significant interaction term.

Table 4
Descriptive Pattern of Mediation

	Integrative Complexity		Dialectical Complexity		Elaborative Complexity	
	Zero-Order	Partial	Zero-Order	Partial	Zero-Order	Partial
Heritability Set 1 (Item)						
Importance ($n = 413$)	.09^	.09^	.17***	.17***	– .01	.00
Involvement ($n = 425$)	.09^	.11*	.17***	.18***	– .01	.00
Experience ($n = 425$)	.09^	.10*	.17***	.18***	– .01	– .00
Confidence ($n = 425$)	.09^	.07	.17***	.14**	– .01	.01
Effort ($n = 425$)	.09^	.08^	.17***	.17***	– .01	– .02
Heritability Set 2 (Item)						
Importance ($n = 733$)	.12***	.11**	– .01	.00	.17***	.15***
Involvement ($n = 424$)	.12**	.13**	.03	.03	.11*	.12*
Experience ($n = 423$)	.12**	.12*	.03	.03	.11*	.10*
Confidence ($n = 423$)	.12*	.13**	.03	.03	.11*	.11*
Effort ($n = 423$)	.12*	.13**	.03	.03	.11*	.11*
Heritability Set 2 (Factor)						
Importance ($n = 763$)	.10**	.08*	.05	.10*	.08*	.01
Involvement ($n = 424$)	.09^	.06	.14**	.14**	– .02	– .05
Experience ($n = 424$)	.09^	.04	.14**	.15**	– .02	– .09^
Confidence ($n = 424$)	.09^	.08^	.14**	.16***	– .02	– .05
Effort ($n = 424$)	.09^	.03	.14**	.12*	– .02	– .06

Note. Zero-order = correlations between heritability and the specific marker of complexity; Partial = correlations between heritability and that marker of complexity while controlling for mediator in left-hand column.
p values for importance one-tailed due to clear directional hypotheses based on previous work (Olson et al., 2001; Tesser, 1993).
^$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

puted the relation between each mediator and the various complexity scores while controlling for heritability (columns 2, 4, and 6 of Table 4). Finally, for each mediator, we computed a Sobel test of mediation to assess the inferential likelihood that the particular variable of interest was a significant mediator for the heritability-complexity relationship (columns 2–4 of Table 5). In each instance, we computed separate sets of analyses for integrative complexity, dialectical complexity, and elaborative complexity. These results are presented in full in Tables 4 and 5.

Table 5
Inferential Tests of Mediation by Heritability Set and Heritability Score

	Relationship to Heritability	Sobel's Test of Mediation		
		Integrative Complexity	Dialectical Complexity	Elaborative Complexity
Heritability Set 1 (Item)				
Importance ($n = 425$)	–.01	<1.00	<1.00	<1.00
Involvement ($n = 425$)	–.28**	–1.55^	–1.01	<1.00
Experience ($n = 425$)	–.06	<1.00	<1.00	<1.00
Confidence ($n = 425$)	–.13**	1.83^	2.34*	–1.86^
Effort ($n = 425$)	.08	1.48^	1.31	1.44
Heritability Set 2 (Item)				
Importance ($n = 763$)	.07*	1.64^	–1.71*	1.85*
Involvement ($n = 428$)	–.04	<1.00	<1.00	<1.00
Experience ($n = 428$)	.05	<1.00	<1.00	<1.00
Confidence ($n = 428$)	–.01	<1.00	<1.00	<1.00
Effort ($n = 428$)	–.02	<1.00	<1.00	<1.00
Heritability Set 2 (Factor)				
Importance ($n = 763$)	.27***	2.50*	–3.73***	4.92***
Involvement ($n = 428$)	.13**	2.02*	–1.27	2.30*
Experience ($n = 428$)	.31**	2.70**	–1.58^	3.84***
Confidence ($n = 428$)	.12*	<1.00	–2.14*	2.21*
Effort ($n = 428$)	.23**	3.27**	1.39	2.96**

Note. Relationship to heritability = correlation between heritability and specific mediator listed in the left-hand column.
p values for importance one-tailed due to clear directional hypotheses based on previous work (Olson et al., 2001; Tesser, 1993). Sobel tests cannot be negative; we use negative values here to indicate a suppression (as opposed to a mediation) effect.
^$p < .15$. *$p < .05$. **$p < .01$. ***$p < .001$.

The first thing to note in Table 4 is that, in the vast majority of cases, a significant heritability-complexity relationship remained after controlling for the various mediators (columns 2, 4, and 6). Thus, although we discuss some significant mediators below, it is worth keeping in mind that the descriptive power of these mediators is (in the main) not particularly impressive, even when inferentially significant.

As can be seen in Table 5, results differed substantially between heritability sets and type of analysis for the Sobel tests. For Heritability Set 1 (which used exclusively item-level analyses), few of the mediating variables had a substantial relation with heritability, so it is unsurprising that almost no significant mediation emerged. Only confidence and involvement showed significant relationships with heritability, and the only significant mediator was confidence (for dialectical complexity). This pattern, taken as a whole, does not support the belief maintenance view.

Interestingly, involvement showed a negative relation to heritability (see Table 5), which is conceptually opposite to that of Tesser's (1993) and Olson and colleagues' (2001) work on attitude strength. It is important to remember that we used a substantially smaller number of items in Set 1 compared to prior research (12 here vs. 40 in Tesser and 30 in Olson et al.) and our own Set 2, increasing the chance that other aspects of a few of the items might drive (or interfere with) an effect for Set 1.

Heritability Set 2 showed a pattern that was partially consistent across both the item and factor heritability scores, although, as Table 5 reveals, the factor heritability scores showed a much stronger pattern of mediation. For the factor heritability scores, four of the five markers of attitude strength and cognitive effort/experience were significant mediators of the heritability-integrative complexity relation. Also, these markers generally showed opposing mediational patterns for the two subcomponents. In particular, several markers (e.g., topic importance) were significantly suppressing the real relation between heritability and dialectical complexity, whereas they were significantly accounting for the relation between heritability and elaborative complexity. The elaborative complexity mediation is consistent with the belief maintenance prediction and is not inconsistent with the biological substrate model. It is hard, however, to know how to interpret the suppression effect. We offer no speculation here, in part because even the significant effects are so descriptively weak that they do not warrant too much space.

As can be seen in Tables 4 and 5, however, mediation analyses on the item heritability scores for Set 2 were weaker and more mixed. It is also important to remember that for mediation analyses on all the sets/scores, although significant mediation was obtained for some of the variables, the substantive sizes of these mediation effects were rather small. Indeed, as Table 4 demonstrates, in the vast majority of cases, even when a mediator was significant, the remaining partial correlation between heritability and complexity also remained significant. Often the reduction upon inclusion of the mediator was only .02 on the *r* scale for significant mediators. Thus, it is worth noting that although some of our mediators showed, for Heritability Set 2, a sensible and significant pattern of mediation, these mediators were clearly not accounting for the majority of the heritability-complexity relationship.

DISCUSSION

First and foremost, the present results suggest that the heritability of an attitude is positively related to the complexity of its representation in the human mind. Using a very large and rich data set—a data set that had not only over 2,000 responses but also over 40 heritability items encompassing the two largest (and independently collected) batteries of heritability estimates currently available—the present results consistently demonstrate that the heritability of an attitude item is positively related to its complexity. The fact that this relation emerged across very different sorts of items, across two independently collected heritability sets (Eaves et al., 1989; Martin et al., 1986; Olson et al., 2001), and across two different types of heritability scores (item vs. factor) is impressive.

Mediation analyses provided a somewhat mixed set of results. First and perhaps most importantly, even when mediators were significant, in the vast majority of cases a significant heritability-complexity relation still remained when the mediator was controlled for. In other words, it is clear from these results that a good (and significant) portion of the complexity-heritability relation is not accounted for by measurements of attitude strength or cognitive effort. Though this underwhelming mediational pattern is on the one hand disappointing, it is also noteworthy that the fact that a significant relationship often remains while controlling for attitude strength and cognitive effort actually helps rule out one possible alternative explanation for our findings. Namely, it might have been argued that items that are hard to interpret or have less meaning to participants produce both lower heritability estimates (due to low variability overall) and lower complexity (due to people's inability to write about ambiguous topics). If that were true, however, one would certainly expect that attitude strength, cognitive experience, and cognitive effort would capture this variable (e.g., almost by definition, people would rate topics they did not understand or that did not have meaning to them as lower in cognitive experience than ones they did understand)—yet, for the most part, a significant heritability-complexity relationship still remained when controlling for these variables. Thus, it seems likely that the relation between heritability and complexity observed here is something more important and deeper in nature.

Nevertheless, it is still worth asking: why might the different sets and (especially) types of heritability approaches yield different results with respect to mediation? Clearly, we can only speculate at this point. Yet one sensible way of viewing these data is that they increased in acuity from Heritability Set 1 to item heritability in Set 2 to factor heritability in Set 2. Set 1 used a comparatively small sample of item heritability scores. Set 2 used a comparatively larger sample that was less prone to anomalous aspects of particular items; thus, its pattern of results was more interpretable. Yet it was still weak. The greatest acuity and power were obtained by combining these items into larger categories. This last point may seem counterintuitive because using the larger categories actually reduced the number of possible heritability scores (from 30 to 9). However, lumping related items into categories can sometimes increase the acuity and power of measures because the loss of numerical power is compensated for by the reliability gained from combining multiple measures of like categories. (For an analogous example from a different area, see Lashley and Kenny's [1998] article demonstrating that power in social relations research depends more on group size—that is, the number of people in a group—than on the number of groups because it is more important to have a small number of large, stable groups than to have a large number of small, unstable groups.) Thus, one possibility is that the factor heritability scores removed a lot of variation from heritability computations that had to do with things unrelated to heritability, thus producing a more accurate estimate of the larger category's heritability. Of course, these points are speculative at the moment, but it is worth noting that Olson et al. (2001) also found substantially stronger heritability-importance/strength relations with the factor heritability scores than with the item heritability scores (importance = .52[factor] to .05[item]; strength = .51[factor] to .17[item]). Our results, then, are not alone in showing this pattern.

This explanation might also help us understand why, more broadly, our work seems to replicate prior work better for Heritability Set 2, and especially at the factor heritability level. The small number of items combined with the item heritability scores for Set 1 made anomalous results more likely; the larger number of items and the factor heritability approach in Set 2 made our results more compatible with other researchers' work that also used 30+items at the base level.

None of these difficulties should undermine this basic and important fact: no matter what heritability set or heritability scores were used here, heritability was positively related to overall integrative complexity. Indeed, this pattern is remarkable, given the differences across samples and methods used here.

Theoretical Implications: Evidence for the Biological Substrate Model

Consistent with a broad model of heritability focusing on the amount of enduring biological substrate allotted to heritable attitudes, the current data suggest that higher heritability is associated with more "cognitive space" devoted to the attitude in the brain, but the specific use of this space varies by topic type. We hypothesize that greater heritability elicits a stronger biological mechanism to *devote more cognitive/physical space to topic domains*, but the content of that space differs for societal versus personal attitudes.

For *societal* topics, which invoked in participants more dialectical (as opposed to elaborative) complexity, the heritability-complexity link is mostly due to participants' increased likelihood to think in dialectically complex ways (i.e., including both positive and negative information about the attitude target). Why might this be? Societal topics, in modern North American society, are more divisive than personal topics, independent of their heritability. Thus, it may be that the implicit motivation aroused by greater heritability makes people likely to seek out the "other side" on societal topics, either to refute that opposing view or to genuinely investigate it, but the inevitable increase in knowledge from exposure to the other side heightens the dialectical complexity of individuals' thinking about the issue. For *personal* topics—which invoke more elaborative complexity, are more personally involving, and are potentially less divisive—the heritability-complexity link is mostly due to participants' increased likelihood to think in elaboratively complex ways (i.e., including multiple points that support the same evaluation of the attitude target). For personal topics, direct experiences with the target may be likely to favor one elaborative direction (e.g., repeated positive experiences with roller coasters), so the implicit drive to devote more space to highly heritable attitudes might result in multifaceted support for one's preferred evaluation. Of course, these ideas are speculative, but they provide some interesting angles for future research.

Are sample differences more favorable to belief maintenance?

One possible interpretation of the present results is more favorable to the belief maintenance view. Namely, if, as we have argued, it is possible that the factor-level analyses from Heritability Set 2 are the most accurate gauge of attitude heritability, one could suggest that those results show mediation analyses partially consistent with the belief maintenance view, and thus maybe our interpretation should focus more on support for that view in the present work.

Though appealing on the surface (and indeed initially appealing to the authors, as we have argued for a belief maintenance view of complexity in other venues; see Conway et al., 2008), we think this interpretation too narrow for multiple reasons. First and foremost, it is simply not consonant with the primary results from the factor heritability scores from Set 2 (or any of the other primary results from either set). Those results show an overall pattern of significantly positive relations between heritability and integrative complexity for the whole sample. Further, they do not show a negative relation between dialectical complexity and heritability (as expected by the belief maintenance view); indeed, the relation is slightly (but not quite significantly) positive. Finally, these results (like the item heritability scores) show a pattern for the societal topics indicative of higher dialectical complexity for more heritable items. The belief maintenance model clearly predicts that this relationship should generally be negative, and certainly should never be positive.

An integration of models: Can biological substrate subsume belief maintenance?

On the other hand, it perhaps would be premature to dismiss the belief maintenance view altogether. Indeed, it is worth noting that, as hinted at in the introduction, the belief maintenance model and the biological substrate model are not fully incompatible. In some ways, the biological substrate model is on a different level of theory than the belief maintenance view, and thus the substrate model may quite possibly *subsume* the maintenance view. Specifically, it may be that, as Tesser (1993) suggested, one of the ways that biological substrate may be "used" is essentially by being devoted to the strong attitudes more likely to induce belief defense. Thus, from a substrate point of view, one might actually *expect* that high heritability can lead to strong attitudes, which may in turn sometimes lead to increased (elaborative) complexity.

Importantly, however, the biological substrate model is not limited to this one mechanism. The biological substrate model suggests only that more neuronal material will be devoted to an attitude; it does not exclude this material from being used in a way more likely to lead to the defense of the attitude, but neither does it limit itself to this use. On the contrary, biological substrate may also be used toward seeking out multiple points of view related to an attitude—a marker of dialectical complexity. Thus, if the biological substrate view is correct, it is perhaps unsurprising that some modest support also emerged for the belief maintenance view, at least for some kinds of topics. Yet clearly there is more than just narrow belief maintenance accounting for the heritability-complexity relationship. In a sense, the more times a positive relationship (or no relationship) emerges between dialectical complexity and heritability, the more it suggests that some kind of biological substrate above and beyond mere belief maintenance accounts for the relationship. Similarly, the more a general overall relationship between integrative complexity and heritability is found, the more this suggests that belief maintenance alone cannot account for the relationship.

Limitations and Caveats

Like all studies, the present study has limitations as well. First, the effect sizes are very small. Thus, although it is highly unlikely the documented relation between heritability and complexity is an inferential fluke, it nonetheless accounts for a relatively small percentage of the complexity of participants' attitudes. Given the large number of situational and personality factors that influence the complexity of attitudes, however, these effect sizes are hardly surprising. Also, it is noteworthy that the heritability measurements themselves are imperfect and collected across different times and cultural contexts. Further, our own data were not collected on the same sample as the heritability estimate, adding a potential gap in the meaning of the words (see, e.g., Tesser, 1993). Thus, small effect sizes were expected and are consistent with other research on heritability also showing small but real effects (e.g., Tesser, 1993)—this was one of the reasons we used such large samples, in anticipation of small effects. To us, it is rather more impressive that, against these potential obstacles, a consistent relation between heritability and complexity was found across such diversity. In the words of Tesser, who was faced with similar small effects in his highly cited 1993 (p. 139) article: "In view of errors inherent in estimating heritability, the differences in sample, and the errors in measuring the response, it is remarkable that anything could be detected!" Nor are such small effects necessarily without meaning or importance (see, e.g., Prentice & Miller, 1992; Tesser, 1993; Yeaton & Sechrest, 1981).

A final limitation pertains to the overall weak pattern of mediation. Although some mediators were significant in ways that make sense, most of the heritability-complexity relation remained nonetheless. This begs the question: what *does* account for the remaining heritability-complexity relation? We think the clearest answer relates to the amount of cognitive space devoted to a given attitude in the brain. It is possible that, in the present study, we simply did not have fine-grained enough measurements of this cognitive space construct. Although we anticipated that our measurements of effort and cognitive experience would capture this variable, these are still crude self-report scales. Future research would do well to use more sophisticated measurements designed to assess (for example) the breadth of the semantic network (e.g., Tyler et al., 2003) associated with a given attitude and other measurements of the cognitive space devoted to that attitude.

ENVOI

Tesser, in his well-known article (1993) on attitudes, warned against a "gee-whiz" response to the effects of attitude heritability. Given the many known consequences of holding complex versus simple beliefs, it is worth finding out why they might be complex or simple. And, if one of the contributing factors in determining complexity involves the heritability of specific attitudes, then this knowledge might importantly shape our own attitudes toward understanding—and potentially changing—the complexity of others' attitudes.

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