Attempts to Prime Intellectual Virtues for Understanding of Science: Failures to Inspire Intellectual Effort

Strategies for effectively communicating scientific findings to the public are an important and growing area of study. Recognizing that some complex subjects require recipients of information to take a more active role in constructing an understanding, we sought to determine whether it was possible to increase subjects' intellectual effort via "priming" methodologies. In particular, we asked whether subconsciously priming "intellectual virtues" (IVs) such as curiosity, perseverance, patience, and diligence might improve participants' effort and performance on various cognitive tasks. In the first experiment, we found no significant differences in either effort or understanding between IV-primed and neutrally-primed individuals across two different priming techniques. The second experiment measured the effect of IV priming on intellectual effort in simpler, shorter-duration puzzles and exploration activities; here we observed an effect, but given its low strength and short duration, we do not believe that priming of intellectual virtues is a promising strategy for science communication.

1. Introduction

Social psychological research into effective strategies for science communication has been on the ascendency in recent decades — and for good reason. Alarm bells have been ringing concerning the abysmal state of science literacy in general in the U.S. and U.K. since at least the 1980s (Bodmer 1985; Miller 1983) and continue today (Miller 2001; PISA 2012). Perhaps most worrisome is the broadly anti-science sentiment we see expressed on important issues like anthropogenic climate change or the safety of childhood vaccines; systematic social psychological research has confirmed what day-to-day experience makes obvious: such issues have become ideologically-entangled in various ways (Funk and Rainie 2015; Kahan *et al.* 2011; Kahan *et al.* 2012). This entanglement only serves to confirm a consensus among experts on science communication that the simple transfer of information — what is often called "The Deficit Model" — is ineffective as a tool for science communication.

The question, then, is what should take its place. A number of approaches have been suggested: from attempting to engage members of the public more fully in the scientific process

(Jasanoff 2004) to "framing" messages in ways that are likely to appeal to a particular audience (Nisbet and Mooney 2007; Nisbet and Scheufele 2009). But as Lewenstein and Brossard (2006) point out, many of these approaches are nevertheless set against the backdrop of the Deficit Model. In particular, they are premised on information-transfer as the primary epistemic transaction.

We believe that social epistemology can play a distinctive and important role in framing alternatives. Many questions deserve attention here. How, for example, does testimony work in noisy and contested social contexts? How should epistemic agents assign and respond to expertise in such contexts (Fricker 1995; Goldman 2001)? Which epistemic state(s) should science communicators (among others) focus on: *knowledge*, *understanding*, or what*?*

Recent studies suggest that in the context of Anthropogenic Climate Change (ACC), one's understanding the causal mechanism of global warming carries predicts their greater propensity to accept expert testimony that ACC is in fact occurring (Ranney and Clark 2016).[1] We have argued elsewhere [REFERENCE SUPPRESSED] that there is reason to believe in general that *understanding* some phenomenon — as opposed to merely *knowing* some facts about it on the say so of others — makes one more epistemically resilient in the face of facile denialist challenges of the sort that are commonly employed in the context of climate science communication (Ahola 2016; Brulle 2014; Carr and Rubenstein 2009; Dunlap and McCright 2010, 2011; McCright and Dunlap 2011; Norgaard 2011; Oreskes and Conway 2010; Wynne 2010).

Unfortunately, as we all know from personal experience, understanding tends to be a more cognitively demanding state; whereas I might come to believe correctly (even *know*) on the passive

[1] This may not seem surprising or noteworthy until one familiarizes themselves with results like Kahan's (2012) that show that the more scientific facts one has at one's disposal, the more likely politics plays a role in determining one's views on ACC and other politically contested issues.

acquiescence to your testimony, in order to *understand* some phenomenon, I must exert some effort. I need to see for myself how things "hang together" (Elgin 2006, 2007; Grimm 2006). But while understanding may be a more valuable epistemic state than knowledge (Kvanvig 2003), it is arguably more difficult to bring about and thus is less attractive as a goal for publically-directed science communication efforts — that is, unless there was a way of motivating agents to engage with information in more intellectually-effortful and critical ways. While some psychologists have suggested that "Need for Cognition" may be a dispositional personality difference between people (Cacioppo and Petty 1982; Cacioppo *et al.* 1996), it's worth asking whether it is a disposition that might be "triggered" or "activated" to different degrees (Haugtvedt and Petty 1992; Lahroodi 2007).

Here we turn to the philosophical discipline of Virtue Epistemology (VE). The origins of VE can be traced back to thinkers such as Aristotle (2000), who claimed that intellectual virtues such as practical wisdom were cultivated through habit and would result in better ethical decision-making; but only recently has it been developed as an alternative to traditional epistemology by thinkers such as Sosa (1980, 2007), Code (1984), and Zagzebski (1996). VE differs from traditional epistemological approaches in that it gives pride of place to the idea of good — or virtuous — intellectual conduct. We can think about such conduct at a variety of levels. For example, Sosa's pioneering account focused on reliable sub-personal belief-forming mechanisms, such as vision, hearing, and memory. Call this Reliabilist VE.

A second strand of thought soon emerged that focused on agents' intellectual "responsibilities," such as being open-minded or intellectually courageous. This Responsibilist approach to VE contrasts with, but (in the view of many) also complements the earlier Reliabilist approach (for discussion, see Battaly 2008). Responsibilist VE encourages reflection on the role that intellectual *character* plays in the active acquisition of knowledge or understanding (Baehr 2012; Roberts and Wood 2007; Zagzebski 2009). Intellectual character virtues are cultivated intellectual dispositions that tend to lead to better intellectual conduct, and so, on balance, to greater knowledge and understanding. For example, in learning about a subject, it is plausible that a person is more likely to understand it well if, all things being equal, his or her learning is driven by an intellectual virtue such as curiosity, or if the inquiry is conducted thoroughly and carefully. This is particularly true in cases such as the public understanding of science, where it is important for agents to believe not just what is comfortable or what agrees with their tribe. By contrast, one need not have any special fondness for truth in order to come to believe correctly that it is raining outside or that a bus is bearing down on us; for this kind of knowledge, we rely on our more or less automatic and generally reliable sensory faculties. Thus, some epistemologists think of the the difference between the Reliabilist and Responsibilist approaches to VE as a matter of whether the knowledge in question is "easy" or "demanding" (Baehr 2012; Battaly 2008; Zagzebski 1996).

Beyond the patient and active work necessary to cultivate such virtues, we wondered if it would be possible to increase their manifestation using subconscious priming — a means of manipulating behavior through introduction of implicit stimuli (Bargh *et al.* 2012). If so, science communicators might be able to employ such stimuli in their efforts to lead non-scientists towards greater understanding of issues that require greater degrees of intellectual effort than others. Priming has been used successfully in a variety of contexts (Aarts *et al.* 2005; Bargh *et al.* 1996; Papies and Hamstra 2010). In one recent study, Gendolla and Silvestrini (2011) demonstrated effects of priming for greater physical exertion; they found that participants who were primed with certain kinds of emotional cues expended more physical effort (and understood that effort differently) compared with subjects in the control condition. Other studies reveal similar results on intellectual *achievement* of various kinds. Apparently, priming achievement words and imagery can engender better performance in experimental, professional, and educational settings (Bargh *et al.* 2001; Crusius and Mussweiler 2012; Engeser *et al.* 2015; Shantz and Latham 2011). For example, in a recent study conducted with German university students, Engeser, Baumann, and Baum (2016) found that achievement primes in textbook passages increased performance on arithmetic and anagram problems.

Might similar implicit priming techniques be used to stimulate the expression of intellectual virtues or increase the exertion of intellectual effort? If so, then supposing that the exercise of these virtues and/or effort is conducive to promoting understanding of scientific theories and concepts, it might carry important implications for both science communication and education. In contrast with attempting to increase public concern or receptiveness to certain kinds of information, as is the goal in framing efforts (Fuchs 2015; Nisbet *et al.* 2011), efforts to prime intellectual virtues would aim to inspire individuals to take a more active role in developing their own understanding.

The two main studies we describe in this paper aimed to determine whether priming intellectual virtues can increase understanding of a complex process — with the ultimate aim of determining whether what we call "intellectual virtue priming" ("IV-priming") could be used to improve understanding of basic scientific concepts or ideas.[2] While an obvious application of this technique would presumably focus on the communication of socially contentious issues, we chose a

[2] Presumably, different intellectual character virtues would be implicated in various and potentially overlapping ways to gains in understanding insofar as they are operative at different stages of inquiry. Curiosity or intellectual courage, for example, might be implicated at the initiation of inquiry whereas thoroughness and carefulness are involved with *sustaining* inquiry. In the experiments described below, our focus is on virtues related to *effort*; accordingly, we posit that greater time spent with the information provided would be the primarily mechanism by which greater effort would lead to better understanding.

non-controversial proxy for a relatively complex causal mechanism — the four-stroke combustion engine — in order to investigate our research question.

Our findings do not support our original hypothesis that IV-priming would increase intellectual effort and thereby understanding. We present results from two pilot studies (§2) and two full studies (§3) as instances of thoroughly vetted but ultimately ineffective attempts to prime a certain range of intellectual virtues; all four studies are discussed in §§4–5. In summary, our results indicate that priming intellectual virtues via sentence scramble and narrative tasks are unlikely to be viable options for increasing the effectiveness of communication efforts for even modestly-complex scientific topics. In §6, we offer some tentative suggestions for further research on science communication strategies related to intellectual virtues and understanding.

2. Pilot Studies

We conducted pilot testing with two different sample populations to examine the effects of priming different categories of intellectual virtues. The first pilot test was conducted with undergraduate students (n=102). The first study served to test the Qualtrics survey with embedded experiment design used in Study 1, and to narrow down the intellectual virtue (IV) priming words to be used in subsequent experiments. The instruments used for conveying a scientific concept and testing understanding can be found in the Methods section of Study 1 (§3.1.1) and in the online Supporting Material. We tested four experimental conditions in the first pilot study; each of the experimental conditions incorporated words from one of three categories of intellectual virtues described by Baehr (2012). These categories (focus, motivation, and endurance), were selected for their hypothesized relevance and suitability to the target task (understanding a simple mechanism). Finding no significant differences between groups for either of the two dependent variables (time spent as a proxy for effort, and grade on understanding questions, detailed in Study 1 below), we conducted the second pilot study with a slightly larger and more diverse sample collected via Amazon Mechanical Turk (MTurk). The second sample of mechanical turk workers (n=144) again showed no significant differences between experimental groups for either of the two dependent variables. Given these results, we narrowed down the IV priming conditions to one category and increased the sample size in an attempt to simplify the experimental design and increase the statistical power of our results in our main studies.

3. Main Studies

Study 1 investigated whether priming specific intellectual virtues, using two different priming techniques, would increase effort and understanding of a four-stroke combustion engine. Here too, we were unable to reject the null hypothesis. We wondered whether this might be due to a duration threshold — that IV-priming might work as we hypothesized, but only for short periods of time. Thus, Study 2 offered participants a shorter and simpler set of tasks to test if exposure to the primes might increase effort. For those who chose to partake in the tasks, time spent, number of tasks performed, and correctness of answers on puzzle responses were recorded to determine whether priming intellectual virtues increased effort and understanding on simpler exercises.

3.1. Study 1

3.1.1. Methods

Participants

In the first study, 186 MTurk workers completed a survey with an embedded experiment. After a brief manipulation check to test for previous knowledge and detection of the experimental design (see below), 10 participants were eliminated from analysis, leaving a total of 176 participants. Demographic information for this sample can be found in the online Supporting Material. Procedure

The Study 1 survey was administered online with Qualtrics Survey Software. The MTurk participants were directed to the Qualtrics survey and were told they were completing an attention task. Two different methods of priming were used in Study 1, a sentence scramble task and a narrative, each containing five IV priming words from Baehr's (2012, 21) virtue categories hypothesized to be most likely to influence effort and understanding for the target task (understanding a simple mechanism); diligence, curiosity, inquisitiveness, determination, and open-mindedness. For each of the priming methods, we also designed a control task. The sentence scramble tasks were modeled from a demonstrably effective sentence-scramble priming methodology (Bargh *et al.* 2001; Srull and Wyer 1979). The experimental sentence scramble tasks included five priming scrambles and five neutral scrambles, while the control scramble consisted of ten neutral scrambles. Participants were asked to use only four of the five words in each scramble to make a complete grammatical sentence, and to complete this task as quickly as possible (Bargh *et al.* 1996). Table 1 includes the scrambles used in this study, with intellectual virtue (IV) priming words in bold (which were of course not set in bold for participants).

IV Primed	**Neutral**
freely with read I **diligence**	bed always breakfast eat in
determination through with practiced she	care yourself take of between
is always George over **curious**	at bushes those main look
amazed **wonder** his him can	knocked Pete over funny it

inquiry gets off **open-minded** pays	the fast Sally newspaper reads
	the assignment she dramatically typed
	keys he his exquisite remembered
	hear coffee she black drank
	refunds there no property are
	loved birthday she celebrate cake

Table 1. Sentence scramble instruments for IV priming and Neutral groups

We incorporated narrative instruments (priming and control), also shown to be effective priming tools (Chiao *et al.* 2010; Stajkovic *et al.* 2006), into Study 1 on the possibility that the lack of effects in the previous pilot studies was only due to ineffectiveness of the sentence scrambles in this context. The narratives were designed with the same intellectual virtue words as were used in the sentence scramble tasks, and the virtue narrative was written to evoke the image of a person employing such virtues. Both narrative tasks can be found in the Supporting Material accompanying the online version of this study.

Participants were randomly assigned to one of four priming conditions (virtue narrative, virtue scrambles, and their respective controls). Following their assigned task, participants were presented with a diagram of a four-stroke combustion engine with a supplementary explanation of the four-stroke combustion process (Figure 1). Participants were timed as they studied this information as a measure of effort. A detailed explanation of the procedure followed on this survey can be found in the online Supporting Material.

Fig 1. Four-Stroke Combustion Engine and Supplementary Explanation. Diagram (Automobile, 2007) and the corresponding process explanation.

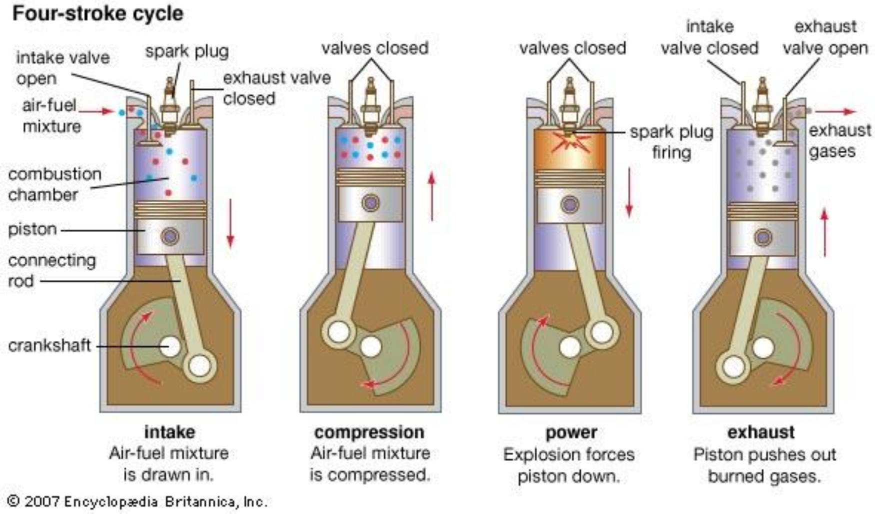

Figure Explanation: The four stroke internal combustion engine cycle begins with the intake stroke. Air enters the engine through the intake valve as the piston moves from TDC (top dead center) to BDC (bottom dead center). During the compression stroke, both intake and exhaust valves are closed and the piston moves from BDC back to TDC, completing the first full revolution of the crankshaft. The spark plug then initiates an electric spark which instantaneously increases both the temperature and pressure. The power stroke occurs once the piston begins to descend due to the large pressure difference above (high pressure) and below (low pressure) the piston, pushing the piston from TDC to BDC. The exhaust valve then opens and the movement of the piston from BDC to TDC forces the exhaust gas out the valve. The exhaust valve closes once the piston reaches TDC and cycle repeats.

Participants were next asked a series of open-ended questions about how the four-stroke engine works. We took care to design the questions so that subjects' *understanding* — rather than rote memorization — was assessed [REFERENCE OMITTED FOR BLIND REVIEW]. Specifically, they would need to make inferences from the information provided or use the information given to them in novel ways (e.g., evaluating counterfactual conditionals relating to the subject matter). Participants were able to reference the diagram while answering the questions. This task was also timed as an additional measure of effort. The questions (including graded point value) are as follows:

Survey Questions

1. How many revolutions of the crankshaft does the engine in the diagram complete per cycle?

(1 point)

2. Where (TDC, BDC, middle) is the piston located at the beginning of the intake stroke? (1 point)
3. Does firing the spark plug cause the air-fuel mixture to expand or contract? (1 point)

   Imagine the following situation: The engine cycle has stopped. Upon closer investigation, it appears that the intake and exhaust valves are both closed, the piston is in the BDC position, and the combustion chamber is full. There are two possible points in the cycle at which the apparent failure could have occurred.
4. At which points in the cycle could these failures have occurred? (4 points)
5. What further information would you need to decide at which of those two points the failure occurred? (2 points)
6. Suppose that the engine stopped in the power stage of the cycle. What possible failure(s) would cause the engine to stop in this stage? (1 point)

Manipulation Check

All participants were asked whether they noticed any themes in the sentence scramble tasks. This manipulation check was included because previous research has shown that participants who are aware that they are being primed tend not to demonstrate behaviors associated with the intended primes (Bargh *et al.* 2012). Additionally, participants in Study 1 were asked whether or not they had previous experience with or background knowledge of the four-stroke engine cycle prior to completion of this study. No participants correctly identified the themes of their sentence scramble conditions. Ten participants indicated that they had significant prior experience or knowledge and were therefore excluded from the analysis.

3.1.2. Results

Three dependent time variables were analyzed to measure effort in Study 1: time spent examining the diagram for the four-stroke combustion engine (Time 1), time spent answering questions on the engine process (Time 2), and the total time spent on both tasks (Total Time). The understanding questions were graded by two independent graders (Intra-class consistency analysis, Cronbach's alpha = .977, $p < .001$), and the grades were averaged for the dependent variable measuring understanding (Grade). Time 1 ranged from .47 to 363.96 seconds (M = 85.83, SD = 66.51), Time 2 ranged from 3.35 seconds to 762.38 seconds (M = 255.83, SD = 153.9), and Total Time ranged from 30.21 seconds to 896.68 seconds (M = 341.67, SD = 188.1). Grades ranged from 0–10 (M = 3.02, SD = 1.86).

A one-way MANOVA between priming conditions (IV scrambles, control scrambles, IV narrative, and control narrative) using Pillai's Trace did not reveal any significant differences on Grade, Time 1, Time 2 or Total Time (V= .05 $F(9, 516) = 1.04$, $p = .409$). The between subjects effects were not significant for Grade ($F(9, 516) = .97$, $p = .407$, Time 1 ($F(9, 516) = 1.01$, $p = .319$), Time 2 ($F(9, 516) = ..52$, $p = .671$), or Total Time, $F(9, 516) = .58$, $p =.627$. Additionally, *post hoc* LSD analyses revealed no significant difference between any of the conditions on either Grade or Total time (all *ps* > .05). An ANCOVA did not reveal any significant differences between priming conditions for Grade when Total Time was held constant, $F(3, 171) = 1.02$, $p= .387$.

Four independent samples t-tests were conducted to determine whether IV primed individuals would demonstrate more effort (for which we use Time 1, Time 2, and Total Time as a proxy) and understanding (as measured by Grade) than neutrally primed individuals. These tests did not reveal any significant differences between groups for Grade ($t(174) = .601$, $p > .05$), Time 1 ($t(174) = -1.25$, $p > .05$), Time 2 ($t(174) = .575$, $p >.05$), or Total Time, $t(174) = .031$, $p > .05$). Means and Standard Errors from the mean for times and grades across all conditions can be seen in Table 2.

Table 2. Means and Standard Errors from the Mean for all times and grades across all four conditions in Study 1

	n	Time 1 mean	Time 1 SE	Time 2 mean	Time 2 SE	Total Time mean	Total Time SE	Grade Mean	Grade SE

IV Scramble	43	96.80	12.29	253.48	27.46	350.28	33.95	2.62	.239
IV Narrative	39	87.80	11.35	243.38	20.54	331.19	25.90	3.27	.327
Control Scramble	46	87.32	9.54	279.41	25.25	366.73	29.68	3.13	.284
Control Narrative	48	72.98	6.94	245.46	18.85	318.44	23.35	3.06	.270

3.2. Study 2

3.2.1. Methods

Participants

In the second study we obtained a sample (n=395) using MTurk in the same manner as Study 1. Demographic information for this sample can be found in the online Supporting Material.

Procedure

This study utilized the same priming and neutral sentence scramble tasks as Study 1 and participants were randomly assigned one of these two conditions in equal numbers. After completion of a sentence scramble task, participants were randomly assigned one of two further conditions, which we have labeled the "Article" condition and the "Puzzle" condition. Participants assigned to the article condition (n=199) were given the option to either read an article about concentration or continue with the survey. Those who chose to read the article were presented with a news piece from Science News. They could then choose to read another article or return to the survey. A total of three Science News articles were available before participants were taken to the demographics questions. Time spent reading each article was recorded, as was the number of articles read. The articles used for Study 2 are available in the Supporting Material.

Participants assigned to the Puzzle condition (n=196) were given the option to complete a puzzle or to continue with the survey. Similar to the Article condition, participants could choose to complete up to five puzzles (anagrams and simple logic puzzles, available in the Supporting Material), or return to the survey at any time. Time spent working on puzzles, number of puzzles, and participant answers to puzzles were all recorded. Each participant received a grade on the puzzle portion of the survey. For each puzzle completed, participants received a point (Puzzle Number, 0–6). Points were also awarded for each correct answer (Correct Answer Score, 0–16). We chose this grading scheme to reward effort in attempting puzzles and success in completing puzzles correctly. The grading scale awarded 0–22 points across 6 questions (Total Puzzle Score). A more detailed explanation of the survey procedure is available in the Supporting Material.

Manipulation Check

As in the previous study, survey respondents were asked if they noticed any theme in the sentences of words of the sentence scramble tasks. None of the participants correctly identified a theme; no participants were eliminated from the analysis.

3.2.2. Results

Study 2 yielded two datasets corresponding to the Article and Puzzle conditions. In the Article dataset, we recorded the number of participants who chose to read an article after completing the priming or neutral sentence scrambles as well as the time spent reading. The priming conditions were first coded into IV-primed or neutral (control) groups. Mean data for choosing to read articles and time spent reading can be seen in Table 3a. Chi squared analysis revealed that there was no significant difference between groups in the number of participants who chose to read an article for further information after completing the sentence scramble task, $\chi^2(1) = .363$, $p > .05$. Independent samples t-tests revealed that IV-primed individuals spent longer reading (M = 22.39 sec, SD = 70.46) than did neutrally primed individuals (M = 15.35 sec, SD = 52.65), however this difference was not significant, $t(199) = .802$, $p > .05$.

In the Puzzle dataset, we recorded the number of participants who chose to try puzzles rather than continue with the survey, the total time spent completing puzzles, and the score received on the puzzles, which included the number of puzzles attempted as well as the number of correct answers, as explained above. Mean scores for these variables can be seen in Table 3b. Chi squared analysis revealed that IV primed individuals were not more likely to choose to try puzzles than individuals in the neutral priming condition, $\chi^2(1) = 2.431$, $p > .05$. Although IV primed participants spent more time completing puzzles (M = 108.51 sec, SD = 148.65) than did participants in the neutrally primed condition (M = 72.85 sec, SD = 127.05), the difference between groups was not significant, $t(194) = 1.81$, $p > .05$.

IV-primed individuals received a significantly higher mean Total Puzzle Score than those individuals primed with neutral sentence scrambles ($t(194) = 2.39$, $p < .05$), however the effect size ($d = 0.34$) was small according to Cohen's (1988) convention (M = 3.59, SD = 4.59 for primed condition, M = 2.20, SD = 3.49 for neutral condition). A significant difference between groups was also found for number of puzzles completed, $t(194) = 2.15$, $p < .05$. Analysis with an ANCOVA revealed, unsurprisingly, that the covariate, number of puzzles completed, was significantly related to Correct Answer Score, $F(1,193) = 186.84$, $p < .001$. After controlling for the effect of puzzle number, there was no significant effect of priming condition on the Correct Answer Score, $F(1,193) = 1.141$, $p = .287$.

Table 3. (A) Number of participants choosing to read an article (n Read/Total) and mean time spent reading articles (Mean Time) across conditions for the Article dataset. (B) Number of participants

choosing to complete puzzles (n Puzzles/Total), mean time spent completing puzzles (Mean Time), mean number of puzzles completed (Mean Puzzles), and mean puzzle scores (Mean Scores) across conditions for the Puzzle dataset.

3A.

	n Read/Total	Mean Time
IV-Primed	14/100 (14%)	22.56
Neutrally Primed	18/99 (18.2%)	15.51

3B.

	n Puzzles/Total	Mean Time	Mean Puzzles	Mean Scores
IV-Primed	51/96 (53.6%)	108.51	1.17	3.59
Neutrally Primed	42/100 (42%)	72.85	0.70	2.20

4. Discussion

When the results of the pilot studies did not support our hypothesis that priming intellectual virtues would motivate some individuals to increase their intellectual effort to understand a mechanical process, we set out to thoroughly test the null hypothesis in two main studies with varied conditions.

The sentence scramble methods followed in our studies have been widely used in priming research and have produced positive priming results in the past (Bargh *et al.* 1996; Bargh *et al.* 2001; Bargh *et al.* 2012), but many have also failed to replicate such results (Doyen *et al.* 2012; Lombardi *et al.* 1987; Shanks *et al.* 2013). In the first main study, we incorporated a narrative priming technique to determine whether the nature of the priming task was influencing the effectiveness of the primes. The results of this first main study did not support our initial hypothesis. Participants receiving the IV priming tasks did not spend significantly more time learning about the four-stroke combustion engine, answering questions about the process, or in total on both tasks than did those receiving the neutral task. Nor were there significant differences in time across the virtue scramble or the virtue narrative conditions. The results strongly suggested that priming these intellectual virtues with this methodology was not an effective means of increasing individual effort to understand, at least as measured by our time-spent proxy. But given that time-spent may not fully reflect effort, we also designed a series of questions to evaluate participant understanding of the engine process. Again, however, we found no significant effects. IV-primed individuals did not score significantly higher on understanding questions than did neutrally-primed individuals. This is further indication that priming intellectual virtues in this manner did not effectively increase understanding of the four-stroke combustion engine in this population.

In many previous priming studies, the action or effect measured occurs relatively quickly after the prime (Abbate *et al.* 2013; Bargh *et al.* 1996; Bargh *et al.* 2001; Bargh *et al.* 2012; Mattiassi *et al.* 2014; Wang and Hamilton 2015). Although little research has been conducted testing the longevity of priming effects, we hypothesized that our four-stroke combustion engine task may have taken too long and required too much effort to be significantly affected by our primes. In an attempt to test this hypothesis, we designed two shorter, simpler series of tasks to be completed after priming for Study 2. The dependent variables measured in the Article Condition of Study 2 were the decision to read *Science News* articles and the time spent reading articles. If individuals primed with intellectual virtues were to be more likely to read articles than those in the control group, this would be an immediate effect of the priming condition that would require little additional effort. IV-primed participants were not, however, more likely to choose to read articles, nor did those primed with intellectual virtues who chose to read articles spend significantly more time reading than those in the control group. One interpretation of these results is that priming intellectual virtues in this manner had no measureable effect on inspiring intellectual curiosity.

In contrast, the Puzzle Condition of Study 2 introduced a bit more complexity into the interpretation of the results of our research. IV-primed individuals were not significantly more likely to choose to complete a puzzle when presented with the opportunity than neutrally primed individuals, as in the Article dataset. However, the Total Puzzle Score *was* significantly higher in the individuals primed with intellectual virtues. Yet controlling for the number of puzzles completed revealed that IV-primed individuals did not actually perform better than control participants on individual puzzles; they merely completed more puzzles.

There are several possible interpretations of these results. One interpretation concerns the effort inspired in persons predisposed to intellectual virtue. In neither the Article nor the Puzzle datasets did priming intellectual virtues inspire more participants to initiate an intellectual task. However, IV-priming may have inspired those who were predisposed to exercising their virtues prior to the study to put forth more effort — i.e. complete more puzzles — than they might have otherwise. Common sense indicates that some individuals are more likely to exhibit intellectual virtues than others, but this does not necessarily mean that they are more intellectually gifted.

Another important consideration concerning the results of Study 2 is that the level of epistemic success necessary to correctly answer the puzzles would likely not be same as that needed to study and interpret the four-stroke engine cycle and questions of the previous studies. If the IV-priming condition was insufficient stimulation to increase accuracy in completing these puzzles, it might not be enough to inspire effort and understanding of a complex scientific phenomenon. This further supports the rejection of our hypothesis that priming intellectual virtues in the manner of this study will increase effort in and understanding of a scientific process.

5. Possible limitations

Let us note the limitations of these studies before discussing their broader implications. We have not shown that the expression of intellectual character virtues — even those concerning only effort — cannot be increased through priming. It is possible that the methods we utilized are simply not the most effective ways in which intellectual virtues might be primed (a possibility that we attempted to allow for by employing two priming methodologies in Study 1). Nevertheless, given the preponderance of studies using similar methodologies to ours in the priming literature (Bargh *et al.* 1996; Bargh *et al.* 2001; Bargh *et al.* 2012; Chiao *et al.* 2010; Ybarra and Trafimow 1998), we are not overly hopeful that the problem here was primarily methodological. Another possible limitation stems from the sample population used, though MTurk has been shown to be a reliable source of data (Buhrmester *et al.* 2011; Paolacci and Chandler 2014). Of course, it is possible that other factors beyond our control in an online survey affected the results. Participants may have been distracted or disinterested, and this could have affected the amount of time they spent on each of the tasks. This is a possible explanation for the relatively large standard deviations seen in our timing data. One possibility for further study could be to conduct these experiments in a room with a moderator in an attempt to minimize potential distractions.

Previous research has shown that when a participant is aware of the intent of the instrument, they become less susceptible to priming (Lombardi *et al.* 1987). A manipulation check at the end of each of the surveys served to identify and eliminate participants for which this issue was of concern. While we took precautions to ensure that the sample populations were not aware of the manipulation of the priming conditions, and that previous knowledge of the four-stroke combustion engine did not skew their understanding scores, there is a possibility that either of these factors could have affected the results. It is also possible that priming intellectual virtues affected a variable related to effort or understanding that was not captured in this study, and therefore did not appear in our measurements and results.

Finally, it might seem this research is based on a conceptual error. The idea that one can, in particular contexts, stimulate improvements in character traits can seem confused. After all, shouldn't intellectual and moral character be seen as more or less fixed and stable? And if we can influence them via irrelevant "situational" factors (e.g., finding a small amount of money), doesn't this call into question the attribution and explanatory salience of "character" in agents' behavior (Alfano 2013; Doris 2002; Ross and Nisbett 1991)? There is much to be said in response to this line of thought (Adams 2006; Baehr 2012, 8–9ff; Sreenivasan 2002); however, the simplest point to make by way of justifying our research methodology to those skeptical of the explanatory significance of character is just that our efforts are best seen as an attempt to increase the *expression* of certain sorts of intellectual character virtues. As mentioned above, in contrast with attempting to increase public concern or receptiveness to certain kinds of information, as is the goal in framing efforts (Fuchs 2015; Nisbet *et al.* 2011), our question was whether priming can be used to "inspire" individuals to take a more active role in developing their own understanding.

6. Implications and Conclusion

It is important to note that the null results of this study do not indicate that priming of intellectual character virtues is not possible; nor are they an example of a failed precise replication study, for the study design was novel. Our findings apply only to the area of priming a relatively narrow class of intellectual character virtues for increasing effort and understanding and not (directly) to any other areas of priming research; this study alone does not disaffirm previous priming research on other topics. Nevertheless, they do join a growing number of instances in which implicit priming methodologies have not shown any significant effect (Abbott 2013; Doyen *et al.* 2012; Harris *et al.* 2013; Shanks *et al.* 2013). The process by which priming occurs is a matter of debate within the psychological research community, with many different mechanisms of action proposed (Engeser *et al.* 2016). Some argue that the limited and specific effects of priming render them less useful in more generalized or applied conditions than might be hoped (Engeser *et al.* 2016; Shanks *et al.* 2013).

One major implication of these results is that priming intellectual virtues may not be possible — or at any rate *practical* — in modalities relevant to large-scale communication. Aside from the possible problems with priming itself, such as the limits to the generalizability of its effects, this limitation could stem from the theorized nature of intellectual virtues themselves. Virtue epistemologists categorize intellectual virtues as intentionally employed and consciously activated while priming itself is thought to work at the subconscious level (Bargh *et al.* 2012; Gendolla and Silvestrini 2011). Although we had hypothesized that an individual could be *subsciously* primed to *consciously* deploy his or her intellectual virtues, this supposition seems to have been incorrect. These results thus cast doubt on this proposed interaction between the subconscious and conscious in this context. One might go so far as to interpret this as lending empirical support to the theoretical claims of Baehr and other virtue epistemologists concerning the cultivated character of intellectual character virtues (2012, 22); such virtues may in fact require conscious exercise and practice to strengthen.[3]

[3] The failure to prime intellectual character virtues might also be seen as offering some support for those opposed to Situationism: while sub-personal stimuli do seem capable of inspiring greater effort in a limited range of cases, the effect size and duration was small. We believe, however, that our results are consistent with both Situationism and its denial; for as we noted above, we believe that had priming be shown to work, it would be consistent with Responsibilist VE approaches and would open further possibilities for attempting to increase agents' epistemic responsibility.

Keeping the limitations of the previous section in mind, these results do have implications for the use of priming as a way to inspire effort and understanding. Specifically, the failure to reject the null hypothesis suggests that attempting to prime epistemic intellectual virtues is unlikely to be an effective way to increase a recipient's understanding of a scientific message. While we cannot say that priming will not be effective in *any* communication effort, the wide variety of attempts to evoke an effect without observing one suggest that the priming of intellectual virtues is not a fruitful area of inquiry for science communication research. Despite the fact that a short duration effect was observed in Study 2, its brevity, specificity, and relative weakness renders it impractical for use in most real-world contexts.[4]

This does not, of course, rule out the prospect for using subconscious priming methodologies in educational settings in ways that may ultimately contribute to enhanced engagement with the process of understanding scientific phenomena — including the practice of science itself [REFERENCE SUPPRESSED]. While future research might attempt to vary our methodologies or explore the replicability of these findings, we believe that effort would be better spent either examining their effects on less demanding epistemic states or attitudes (e.g., basic acceptance of a piece of information, or a tendency to treat certain communicators as trustworthy) or focusing on the development of understanding through means that consciously engage subjects.

REFERENCES

[4] It is also important to note that these results have no clear application to the effectiveness of communication techniques such as framing. Our results relate only to effort and understanding of a scientific process, and have no clear bearing on willingness to be receptive to new information (as with issue framing) (Fuchs 2015; Nisbet *et al.* 2011; Nisbet and Mooney 2007).

Aarts, Henk, Tanya L Chartrand, Ruud Custers, Unna Danner, and Giel Dik (2005) "Social Stereotypes and Automatic Goal Pursuit," *Social Cognition* 23 (6):465–490.

Abbate, Constanza Scaffidi, Stefano Ruggieri, and Stefano Boca (2013) "Automatic Influences of Priming on Prosocial Behavior," *Europe's Journal Of Psychology* 9 (3):479–492.

Abbott, Alison (2013) "Disputed Results a Fresh Blow for Social Psychology. Failure to Replicate Intelligence-priming Effects Ignites Row in Research Community," *Nature* 497:16.

Adams, Robert (2006) *A Theory of Virtue*. Oxford: Oxford University Press.

Ahola, Salla (2016) "Why (Not) Disagree? Human Values and the Readiness to Question Experts' Views," *Public Understanding of Science* DOI: 10.1177/0963662516637818 (Online First).

Alfano, Mark (2013) *Character as a Moral Fiction*. Cambridge: Cambridge University Press.

Aristotle (2000) *Nicomachean Ethics*. Translated by J. Sachs. Newbury, MA: Focus Pub./R. Pullins.

Baehr, Jason (2012) *The Inquiring Mind: On Intellectual Virtues and Virtue Epistemology*. Oxford: Oxford University Press.

Bargh, John A., Mark Chen, and Lara Burrows (1996) "Automaticity of Social Behavior: Direct Effects of Trait Construct and Stereotype Activation on Action.," *Journal of Personality and Social Psychology* 71:230–244.

Bargh, John A., Peter M. Gollwitzer, Annette Lee-Chai, Kimberly Barndollar, and Roman Trotschel (2001) "The Automated Will: Nonconscious Activation and Pursuit of Behavioral Goals.," *Journal of Personality and Social Psychology* 81 (6):1014–1027.

Bargh, John A., Kay L. Schwander, Sarah E. Hailey, Rebecca L. Dyer, and Erica J. Boothby (2012) "Automaticity in social-cognitive processes," *Trends in Cognitive Sciences* 16 (12):593-605.

Battaly, Heather (2008) "Virtue Epistemology," *Philosophy Compass* 3 (4):639–663.

Bodmer, Walter (1985) *The Public Understanding of Science: Report of a Royal Society Ad Hoc Group Endorsed by the Council of the Royal Society*. London: The Royal Society; available online: http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/1985/10700.pdf.

Brulle, Robert J. (2014) "Institutionalizing Delay: Foundation Funding and the Creation of U.S. Climate Change Counter-Movement Organizations," *Climatic Change* 122:681–694.

Buhrmester, Michael, Tracy Kwang, and Samuel D. Gosling (2011) "Amazon's Mechanical Turk: A New Source of Inexpensive, Yet High-Quality Data?," *Perspectives on Psychological Science* 6 (1):3–5.

Cacioppo, John T., and Richard E. Petty (1982) "The Need for Cognition," *Journal of Personality and Social Psychology* 42:116–131.

Cacioppo, John T., Richard E. Petty, Jeffrey A. Feinstein, and W. Blair G. Jarvis (1996) "Dispositional Differences in Cognitive Motivation: The Life and Times of Individuals Varying in Need for Cognition.," *Psychological Bulletin* 119:197–253.

Carr, Mary-Elena, and Madeleine Rubenstein (2009) "Challenges to Authority: Understanding Critiques of the Intergovernmental Panel on Climate Change," *Union Seminary Quarterly Review* 63:42–66.

Chiao, Joan Y., Tokiko Harada, Hidetsugu Komeda, Zhang Li, Yoko Mano, Daisuke Saito, Todd B. Parrish, Norihiro Sadato, and Tesuya Iidaka (2010) "Dynamic Cultural Influences on Neural Represntations of the Self," *Journal of Cognitive Neuroscience* 22 (1):1–11.

Code, Lorraine (1984) "Toward a 'Responsibilitst' Epistemology," *Philosophy and Phenomenological Research* 65:29–50.

Crusius, Jan, and Thomas Mussweiler (2012) "To Achieve or Not to Achieve? Comparative Mindsets Elicit Assimilation and Contrast in Goal Priming.," *European Journal of Social Psychology* 42 (6):780–788.

Doris, John (2002) *Lack of Character*. Cambridge: Cambridge University Press.

Doyen, Stéphane, Olivier Klein, Cora-Lise Pichon, and Axel Cleeremans (2012) "Behavioral Priming: It's All in the Mind, but Whose Mind?," *PLOS ONE* 7:e29081.

Dunlap, Riley E., and Aaron M. McCright (2010) "Climate Change Denial: Sources, Actors and Strategies," in Constance Lever-Tracy (ed.), *Routledge Handbook of Climate Change and Society*. London: Routledge.

Dunlap, Riley E., and Aaron M. McCright (2011) "Organized Climate Change Denial," in John S. Dryzek, Richard B. Norgaard and David Schlosberg (eds.), *The Oxford Handbook of Climate Change and Society*. Oxford: Oxford University Press.

Elgin, C. Z. (2006) "From Knowledge to Understanding," in Stephen Hetherington (ed.), *Epistemology Futures*. Oxford: Oxford University Press.

Elgin, C. Z. (2007) "Understanding and the Facts," *Philosophical Studies* 32:33–42.

Engeser, Stefan, Nicola Baumann, and Ingrid Baum (2016) "Schoolbook Texts: Behavioral Achievement Priming in Math and Language," *PLOS ONE* 11:e0150497.

Engeser, Stefan, Benjamin Euen, and Wilfriend Bos (2015) "Performance Thematic Content of Textbooks and Educational Performance in Primary School," *Journal of Educational Psychology* 29:65–75.

Fricker, Elizabeth (1995) "Telling and Trusting," *Mind* 104:393–411.

Fuchs, Hans A. (2015) "From Stories to Scientific Models and Back: Narrative framing in modern macroscopic physics," *International Journal of Science Education* 37 (5-6):934-957.

Funk, Cary, and Lee Rainie (2015) *Public and Scientists' Views on Science and Society*. Washington, D.C.: Pew Research Center.

Gendolla, Guido H., and Nicolas Silvestrini (2011) "Smiles Make it Easier and So Do Frowns: Masked Affective Stimuli Influence Mental Effort," *Emotion* 11 (2):320–328.

Goldman, Alvin (2001) "Experts: Which Ones Should You Trust?," *Philosophy and Phenomenological Research* LXIII (1):85–110.

Grimm, Stephen (2006) "Is Understanding a Species of Knowledge," *British Journal for the Philosophy of Science* 57:515–535.

Harris, Christine R., Noriko Coburn, Doug Rohrer, and Harold Pashler (2013) "Two Failures to Replicate High-Performance-Goal Priming Effects," *PLOS One* 8 (8).

Haugtvedt, Curtis P., and Richard E. Petty (1992) "Personality and Persuasion: Need for Cognition Moderates the Persistence and Resistance of Attitude Changes," *Journal of Personality and Social Psychology* 63:308–319.

Jasanoff, Sheila, ed. (2004) *States of Knowledge: The Co-Production of Science and Social Order*. Abingdon, UK: Taylor & Francis.

Kahan, Dan M., Hank Jenkins-Smith, and Donald Braman (2011) "Cultural Cognition of Scientific Consensus," *Journal of Risk Research* 14 (2):147–174.

Kahan, Dan M., Maggie Wittlin, D. Braman, Paul Slovic, Ellen Peters, Lisa Larrimore Ouellette, and Gregory Mandel (2012) "The Polarizing Impact of Science Literacy and Numeracy on Perceived Climate Change Risks," *Nature Climate Change* 2:732–735.

Kvanvig, Jonathan (2003) *The Value of Knowledge and the Pursuit of Understanding*. Cambridge: Cambridge University Press.

Lahroodi, Reza (2007) "Evaluating Need for Cognition: A Case Study in Naturalistic Epistemic Virtue Theory," *Philosophical Psychology* 20:227–245.

Lewenstein, Bruce, and Dominique Brossard (2006) *Assessing Models of Public Understanding in ELSI Outreach Materials*. Final Report for U.S. Department of Energy Grant DE-FG02-01ER63173: https://www.assembla.com/spaces/cdr/documents/dScyiuUzGr3QIGeJe5aVNr/download/LewensteinandBrossard.2006.DOEfinalreport.pdf.

Lombardi, Wendy J., E. Tory Higgins, and John A. Bargh (1987) "The Role of Consciousness in Priming Effects on Categorization Assimilation Versus Contrast as a Function of Awareness of the Priming Task," *Personality and Social Psychology Bulletin* 13 (3):411–429.

Mattiassi, Alan D. A., Sonia Mele, Luca F. Ticini, and Cosimo Urgesi (2014) "Conscious and Unconscious Representations of Observed Actions in the Human Motor System," *Journal of Cognitive Neuroscience* 26 (9):2028–2041.

McCright, Aaron M., and Riley E. Dunlap (2011) "The Politicization of Climate Change and Polarization in the American Public's Views of Global Warming, 2001–2010," *The Sociological Quarterly* 52:155–194.

Miller, Jon D. (1983) "Scientific Literacy: A Conceptual and Empirical Review," *Daedalus* 112:29–48.

Miller, Steve (2001) "Public Understanding of Science at the Crossroads," *Public Understanding of Science* 10:115–120.

Nisbet, Matthew C, and Chris Mooney (2007) "Framing Science," *Science* 316:56.

Nisbet, Matthew C., Edward Maibach, and Anthony Leiserowitz (2011) "Framing Peak Petroleum as a Public Health Problem: Audience Research and Participatory Engagement in the United States," *American Journal of Public Health* 101 (9):1620–1626.

Nisbet, Matthew C., and Dietram A. Scheufele (2009) "What's Next for Science Communication? Promising Directions and Lingering Distractions," *American Journal of Botany* 96 (10):1767–1778.

Norgaard, Kari Marie (2011) *Living in Denial: Climate Change, Emotions, and Everyday Life*. Cambridge, MA: The MIT Press.

Oreskes, Naomi, and Erik M. Conway (2010) *Merchants of Doubt*. New York: Bloomsbury Press.

Paolacci, Gabriele, and Jesse Chandler (2014) "Inside the Turk Understanding Mechanical Turk as a Participant Pool," *Current Directions in Psychological Science* 23 (3):184–188.

Papies, Esther K., and Petra Hamstra (2010) "Goal Priming and Eating Behavior: Enhancing Self-Regulation by Environmental Cues," *Health Psychology* 29 (4):384–388.

PISA (2012) *Results from PISA 2012: United States*. Paris: Organisation for Economic Co-operation and Development.

Ranney, Michael Andrew, and Dav Clark (2016) "Climate Change Conceptual Change: Scientific Information Can Transform Attitudes," *Topics in Cognitive Science* 8:49–75.

Roberts, Robert C., and W. Jay Wood (2007) *Intellectual Virtues: An Essay in Regulative Epistemology*. Oxford: Oxford University Press.

Ross, Lee, and Richard E. Nisbett (1991) *The Person and the Situation: Perspectives of Social Psychology*. New York: McGraw-Hill Publishers.

Shanks, David R., Ben R. Newell, Eun Hee Lee, Divya Balakrishnan, Lisa Ekelund, Zarus Cena, Kavvadia Fragkiski, and Christopher Moore (2013) "Priming Intelligent Behavior: An Elusive Phenomenon," *PLOS One* 8 (4):1-9.

Shantz, Amanda, and Gary Latham (2011) "The Effect of Primed Goals on Employee Performance: Implications for Human Resource Management," *Human Resource Management* 50 (2):289–299.

Sosa, Ernest (1980) "The Raft and the Pyramid: Coherence versus Foundations in the Theory of Knowledge," *Midwest Studies in Philosophy* 5:3–25.

Sosa, Ernest (2007) *Apt Belief and Reflective Knowledge, Volume 1: A Virtue Epistemology*. Oxford: Oxford University Press.

Sreenivasan, Gopal (2002) "Errors about Errors: Virtue Theory and Trait Attribution," *Mind* 111:47–68.

Srull, Thomas K., and Robert S. Wyer (1979) "The Role of Category Accessibility in the Interpretation of Information About Persons: Some Determinants and Implications," *Journal of Personality and Social Psychology* 37 (10):1660–1672.

Stajkovic, Alexander D., Edwin A. Locke, and Eden S. Blair (2006) "A First Examination of the Relationships Betwen Primed Subconscious Goals, Assigned Conscious Goals, and Task Performance," *Journal of Applied Psychology* 91 (5):1172–1180.

Wang, Yin, and Antonia F. de C. Hamilton (2015) "Anterior Medial Prefontal Cortex Implements Social Priming of Mimicry," *Social Cognitive and Affective Neuroscience* 10 (4):486–493.

Wynne, Brian (2010) "Strange Weather, Again: Climate Science as Political Art," *Theory, Culture & Society* 27:289–305.

Ybarra, Oscar, and David Trafimow (1998) "How Priming the Private Self or Collective Self Affects the Relative Weights of Attitudes and Subjective Norms," *Personality and Social Psychology Bulletin* 24 (4):62.

Zagzebski, Linda T. (1996) *Virtues of the Mind: An Inquiry into the Nature of Virtue and the Ethical Foundations of Knowledge*. Cambridge: Cambridge University Press.

Zagzebski, Linda T. (2009) *On Epistemology*. Belmont, CA: Wadesworth.