Comparing predictions from the Elaboration Likelihood Model and a Bayesian model of argumentation

Jens Koed Madsen (j.madsen2@lse.ac.uk)
Department of Psychological and Behavioural Science,
London School of Economics and Political Science, Houghton Street, WC2A 2AE, London, UK

Michelle Cho Sze Wong (c.wong28@lse.ac.uk)
Department of Psychological and Behavioural Science,
London School of Economics and Political Science, Houghton Street, WC2A 2AE, London, UK

Abstract

Much of our knowledge comes from other people. In considering how argument quality and source reliability influences message persuasiveness, we conduct a comparison of the Elaboration Likelihood Model of Persuasion and the Bayesian Model of Argumentation, which are based on different assumptions. Participants were asked to judge a fictitious character's degree of belief in a claim given evidence. To test competing predictions, we manipulate the character's elaboration level, the argument's quality, and the source's reliability. The elaboration did not moderate the main effects of argument quality and source reliability, as they both were integral to the overall message strength in both high and low elaboration conditions. Bayesian predictions have better fit with the observed data, whilst ELM predictions did not align well. Overall, the BM is supported, but we discuss how this model could be further improved while the ELM is contested.

Keywords: Argumentation; Argument strength; Bayesian source credibility model; Elaboration-Likelihood Model

Introduction

Every day we get information from multiple sources, which forms the basis of the belief and opinions we hold (Hahn et al., 2012, p. 21). In fact, much of what we know is acquired from the testimonies of others. As Hahn and Hornikx (2016, p. 1833) suggest, reasoning and argumentation is essential 'for humans to learn, make decisions, and interact with others'. Given the importance of this endeavor, there have unsurprisingly been competing psychological models to describe how people reason through testimonies and arguments.

One approach is the Elaboration Likelihood Model of Persuasion (ELM; Petty and Cacioppo, 1981) developed from the social psychological study of persuasion. The ELM is a dual-process theory that posits two persuasion routes – the *central route*, which is effortful and slow, involves the processing of argument quality, and the *peripheral route*, which is less effortful and fast, involves the processing of source reliability. Another approach is the Bayesian Model of Argumentation (BM; Hahn & Oaksford, 2007) arising from the discipline of argumentation. It is a normative framework to reasoning that takes point of departure in people's subjective prior degrees of belief in the hypothesis, the reliability of the source, and the strength of the evidence to predict how people should update their beliefs when they encounter arguments and new information from more or less reliable sources.

The ELM and the BM both attends to the influences of argument quality and source reliability in the investigation of attitude/belief change. However, they rely on different assumptions, which in some cases yields different predictions as to how argument and source function in human reasoning processes. This paper conducts a comparison of the two models through an experimental survey to explore which approach has a better fit with observed responses in these cases. To our knowledge, this is the first ever attempt to compare the ELM and the BM simultaneously in a single study. The goal of this research is to explore whether the ELM or the BM provides a more accurate account of the functions of argument quality and source reliability in influencing message persuasiveness.

Literature review

In the following, we describe and consider predictions from the ELM and BM to contextualize the experiment.

Elaboration-Likelihood Model (ELM)

Introduced by Petty and Cacioppo in 1981, the ELM is a dual-process theory for persuasion with the aim to provide 'a general framework for organizing, categorizing, and understanding the basic processes underlying the effectiveness of persuasive communication' (Petty & Cacioppo , 1986a, p. 125). Ever since its inception, it has been widely applied, including areas like marketing (e.g. Bitner and Obermiller, 1985), mass-media advertising (e.g. Petty et al., 1983), politics (e.g. Chmielewski, 2012), and other fields.

At the heart of the ELM is the elaboration continuum, which reflects the amount of cognitive effort a person is willing and able to devote to message processing (Petty and Cacioppo, 1984, p. 668). Anchored at two ends of the continuum is *the central route to persuasion*, and *the peripheral route to persuasion.*

In the central route, high cognitive effort is dedicated, one would engage in diligent consideration of all issue-relevant information, and carefully evaluate the true merits of the message argument. In the peripheral route, minimal cognitive work is involved, one would engage in less thoughtful issue-

In M. Goldwater, F. K. Anggoro, B. K. Hayes, & D. C. Ong (Eds.), *Proceedings of the 45th Annual Conference of the Cognitive Science Society.*

relevant thinking, and rely on shallow non-content persuasion cues like source credibility (e.g. Heesacker et al., 1983; Chaiken and Maheswaran, 1994). As a result of the extensive cognitive work, attitudes formed via the central route is more enduring and more resistant to counter-persuasion (Cialdini et al., 1981; Cook and Flay, 1978). The likelihood to elaborate depends on the *motivation to elaborate* and the *ability to elaborate*. Motivation may be moderated by personal relevance (e.g. Kruglanski and Van Lange, 2012), need for cognition (e.g. Zhang and Buda, 1999), and attitude (e.g. Homer, 1990) while ability may be determined by distraction (e.g. Petty and Cacioppo, 1983), message repetition (e.g. Schumann et al., 1990), and prior knowledge (e.g. Alba and Hutchinson, 1987). The distinction of the central-peripheral cognitive processing can be supported by McGuire's (1969) characterisation of human as "lazy organisms" – that we minimise cognitive resources if possible. As Petty and Cacioppo (1986a, p. 128) explained, given our limited time and capacity, it would not be adaptive for us to scrutinise everything meticulously

Of the different peripheral cues studied within the ELM framework, source reliability is most relevant here. The functions of source factors were discussed by Petty and Cacioppo (1984) who suggest that, in low elaboration, source factors serve as simple peripheral cues for quick acceptance or rejection of the argument. Comparatively, in high elaboration, source information may be integrated as part of all the issue-relevant information that people scrutinise in evaluating the argument persuasiveness

Some support (e.g. Johnson and Scileppi, 1969; Petty, Cacioppo, and Goldman, 1981) has been provided for Petty and Cacioppo's (1984) propositions. However, further intricacies have also been suggested as to how source reliability influences message persuasiveness. For instance, Chaiken and Maheswaran (1994) found that in cases where the task importance is high and the message is ambiguous, people engaged in central processing of message content while the heuristic processing of source credibility biased people's attitude judgement

Heesacker et al. (1983) provides another example of the complexity of source reliability. Although they found source credibility to only affect the attitude change of subjects with inherently low propensity to scrutinise message, it was suggested that the source credibility effect was not to directly increase the message persuasiveness but to encourage message scrutiny. Finally, there are studies that failed to replicate the ELM more broadly. To name a few, Te'eni-Harari (2007) found the ELM unapplicable to advertising effectiveness between high and low involvement groups for children and early adolescents. SanJosé-Cabezudo et al. (2009) found that when one is highly motivated, both the central route and peripheral route act together to give a combined influence, which would not have been accepted given the ELM's trade-off postulate. In short, ELM studies on the effects of source credibility have produced mixed results, and its effects is much more complicated than it appears on the surface. However, broadly, the ELM literature tends to regard source credibility as a heuristic cue that mainly gets activated via the peripheral route. There is much more that can be said about the ELM, however, it is beyond the scope of the current paper to discuss them all. For a review, see Kitchen et al. (2014).

Bayesian model of argumentation (BM)

The Bayesian approach to reasoning and argumentation proposes a probabilistic treatment of arguments, such that degrees of belief are represented as subjective probabilities between 0 and 1, and that the updating of belief in a hypothesis given evidence is captured by the Bayes Theorem.

This approach has been put forward as an alternative to the logicist paradigm in the psychology of reasoning, where propositions can only be dichotomously true or false. The Bayesian viewpoint argues that, living in an uncertain world, human reasoning should be thought of as calculating uncertainty probabilistically rather than calculating certainty logically (Oaksford and Chater, 2007, p. 7). Like the ELM, Bayesian approaches have been applied to numerous areas such as cognition (Tenenbaum et al., 2011), argumentation (Hahn and Oaksford, 2007), and fallacies (Harris et al., 2012), and more.

Bayes' theorem estimates the posterior degree of belief and expresses how a rational agent should revise their belief in a hypothesis, h when faced with new evidence E, captured by Bayes' theorem.

$$p(h|e) = \frac{p(h)p(e|h)}{p(h)p(e[h) + p(\neg h)p(e|\neg h)}$$

where, $p(h|e)$, represents the posterior degree of belief in the hypothesis, h. The posterior degree of belief is a function of what the person believed about the hypothesis before hearing the new evidence called the prior belief, $p(h)$, the conditional probability of observing the evidence, e, if the hypothesis was true $(e|\neg h)$ and the conditional probability of observing the evidence, e, if the hypothesis was false $(e|\neg h)$.

Of specific relevance to the current paper, Bayesian models of source credibility describe how people should integrate information from more or less reliable sources (Bovens & Hartmann, 2003). Hahn et al. (2009) argue the relationship between the message content and its source in determining the evidential strength, is not additive but multiplicative.

Harris et al. (2015) further expanded on the concept of source reliability and distinguished between *epistemic authority* (i.e. *expertise*), which is 'the authority of those with superior knowledge in a specific field' (Harris et al., 2015, p. 3), and *trustworthiness*, which is 'the likelihood that a person will not deliberately present wrong or misleading information' (Madsen, 2016, p. 165). In general, people are found to be sensitive to priors and likelihoods and the BM replicates across cultures (Karaslaan et al., 2018).

Comparing the ELM and BM

While the ELM and the BM resemble each other in some ways, they conflict each other in other ways; they also each have their own strengths and weaknesses, as well as aspects that both models fall short of. To begin with, the two models have

a common departure point in their mutual recognition of argument content and source characteristics in effecting message persuasiveness and in inducing attitude change. In general, both models agree that stronger arguments and more reliable sources would lead to more positive change of belief.

However, the functions of argument and source are different in the two models. In the ELM, depending on their elaboration level, one would process either argument content or source characteristics; and the two variables are considered as alternatives (Hahn et al., 2020, p. 349) as stated in the trade-off postulate. Even if multi- channel processing is not precluded, the ELM at best involves additive elaborative processing (Hahn et al., 2009, p. 349). The BM, contrarily, does not concern itself with the elaboration likelihood; argument content and source characteristics are always both processed, and they even interact to influence each other's intrinsic strength (Hahn et al., 2009; Hahn et al., 2012)

In terms of their strengths and weaknesses, the BM goes beyond the ELM in providing concrete predictions that can be tested. As Hahn and Hornikx (2016, p. 1868) discussed, 'the Bayesian framework not only has a well-developed normative basis, but also it is sufficiently computationally explicit that probabilistic reconstruction captures not just the quantitative impact of individual variables, but also their interrelationships'. This contrasts with the ELM's mere descriptive nature and addresses ELM's issue of being too flexible and unfalsifiable. As such, being normative and predictive, the BM has more rigour than the ELM.

Yet, the ELM is arguably better in acknowledging elaboration effects, which have not been considered in the BM. Humans appear to have some heuristics and biases (Tversky & Kahneman, 1974), which the ELM acknowledges directly through the peripheral route. Indeed, Madsen (2016) observed greater noise for Bayesian predictions on the individual level than on the population level, which could be due to other factors not specified in the BM, like cultural differences. Additionally, he also speculated some "recency bias" in his data, suggesting that humans are not perfectly Bayesian. Therefore, the BM may be too rigid.

The current study

In light of their contradictory assumptions, this study sets out to compare the ELM and the BM. Several researchers (e.g. Hahn and Oaksford, 2007; Hahn et al., 2009, p. 349; Harris et al., 2015, p. 28) have briefly noted how the BM may pose challenges to the ELM. Yet, there are no studies to date that have tested the two models concurrently. To do so, it is vital to compare the two models with the same experimental conditions using the same sample. Since the two models originated from different disciplines, they usually have different theoretical focus (Hahn et al., 2009, p. 349); different studies may have also manipulated the variables differently (Kitchen et al., 2014, p. 2043).

In the experiment that follows, all the relevant variables of elaboration, argument quality, and source reliability are manipulated; it is designed to examine whether people's reasoning processes align more with the ELM's or the BM's propositions, and in what ways specifically. To streamline the design, we investigate only high vs. low conditions for all the variables, which suffices for an initial exploration of model fits. A model-fitting exercise is also performed to test the degree to which the observed data approximated the BM's quantitative predictions. The expected message impacts for the current study design are tabulated in Table 1, based on the two models' respective assumptions

Elaboration	Argument	Source Credibility	ELM Predictions		BM Predictions	
			Cue	Strength	Cue	Strength
Low	Weak	Unreliable	source	Low	argument + source	Low
		Reliable	source	High	argument + source	Moderate
	Strong	Unreliable	source	Low	argument + source	Moderate
		Reliable	source	High	argument + source	High
High	Weak	Unreliable	argument	Low	argument + source	Low
		Reliable	argument	Low	argument + source	Moderate
	Strong	Unreliable	argument	High	argument + source	Moderate
		Reliable	argument	High	argument + source	High

Table 1: Competing model expectations for conditions

Given the previous success of Bayesian modelling, as compared to the mixed findings found in ELM studies, it is hypothesised that the BM has stronger explanatory power in accounting for the influences of argument quality and source reliability in human reasoning. The formal hypotheses are

H1) *Elaboration likelihood have no moderating effect on the influences of argument quality and source reliability in belief revision*

H1a) *Argument quality have significant main effects in both high and low elaboration conditions.*

H1b) *Source reliability have significant main effects in both high and low elaboration conditions*

H2) *Argument quality and source reliability have significant interaction effects in both high and elaboration conditions*

Participants

A priori power analysis was conducted using the software *G*Power 3.1* (Faul et al., 2009), to determine the sample size needed to minimise type-I and type-II errors and ensure a strong statistical power (Mayr et al., 2007, p. 52). Using *effect size (f)* = 0.2, *significance level (α)* = 0.05, *power level (1-β)* = 0.8, *correlation among repeated measures*= 0, *nonsphericity correction* = 0.5; a sample size of 114 is recommended. To be conservative and account for sampling error, 260 participants (125 females, 132 males, and 3 non-binary) were recruited from Prolific. This results in roughly 130 participants per between-subjects variable group (high elaboration vs. low elaboration). Participants had to be aged 18+, Native English speakers, and with no prior background in psychology. Participants were paid an equivalent of £8/hour for participation. Two attention-checks were included to ensure that participants were engaging with the survey; submissions that failed both attention-checks were rejected

Design and materials

A 2 x 2 x 2 mixed design was employed, where *elaboration* (high vs. low) is a between- subjects variable, while *argument*

quality (strong vs. weak) and *source reliability* (reliable vs. unreliable) are within-subjects variables.

To incorporate the within-subject manipulations, four independent fictitious scenarios were designed: (a) music headphone purchase, (b) hiking shoes purchase, (c) stock investment, and (d) horseracing betting. All the character names/brands/products were made-up so that participants' pre-existing attitudes would not bias their judgement.

Each scenario had the same structure. A description of a female recipient was introduced with a high/low *elaboration* condition. She was also described as making a purchasing decision between two items (e.g. two types of headphones). Then, employing the typical third-party argument evaluation paradigm used in most Bayesian studies (e.g. Oaksford and Hahn, 2004; Hahn et al., 2009), participants were presented a dialogue between two interlocutors, where a male proponent suggests the female recipient should purchase an item (e.g. one of the headphones). The decision to employ a third-person paradigm was made so participants could be split into high vs. low elaboration groups.

The description of the male proponent contained the *trustworthiness* (i.e. *source reliability*) manipulation; whilst the dialogue included the *argument quality* manipulation and the *expertise* (i.e. *source reliability*) manipulation. All argument claims provided positive evidence for the proposition.

Variable manipulation

The *elaboration* manipulation was operationalised through depicting the female recipient as having either both high *ability* and high *motivation*, or both low *ability* and low *motivation*. The ELM suggested that ability may be dependent on issue-relevant knowledge (Petty & Cacioppo, 1986b), and motivation may be dependent on 'personal relevance and the consequences of the persuasive appeal' (Petty and Cacioppo, 1984, p. 669). We manipulate *ability* by varying the character's amount of experience in the field; whilst *motivation* was manipulated by describing the character as having an intrinsic or extrinsic purchasing intention, and by varying the stakes of the purchase. Since *elaboration* is a between- subjects variable, across the four scenarios, each participant saw either exclusively all high *elaboration* or all low *elaboration* conditions.

Argument quality was manipulated following Petty et al.'s (1981, p. 850) definition – strong messages 'provided persuasive evidence (statistics, data, etc.)' to support its claim; whilst weak messages relied on subjective personal opinions to support its position. Finally, following Harris et al. (2015), the *source reliability* manipulation involved either high/high or low/low *trustworthiness* and high *expertise*. We manipulate *trustworthiness* by portraying the male proponent as someone having a good intent or a deceptive intent; and *expertise* was manipulated by stating the claim to be originating from the speakers' own extensive knowledge, as opposed to quoting from someone with an somewhat issue-irrelevant occupation. All stimuli was piloted prior to the study to ensure high and low levels of *elaboration*, *argument quality*, and *source reliability*. Having seen the dialogue, participants provided their posterior degree of belief on how likely the female protagonist would be to purchase the item suggested by the male protagonist.

Responses were recorded probabilistically to ensure comparability with Bayesian predictions (generated by adding priors from the pilot study to the Harris et al., 2015 model with the following conditional probability table).

	Hypothesis = "True" (H)				Hypothesis = "False" (¬H)			
	Reliable Source (Rel)		Unreliable Source (Unrel)		Reliable Source (Rel)		Unreliable Source (Unrel)	
	Strong Argument (Strong)	Weak Argument (Weak)	Strong Argument (Strong)	Weak Argument (Weak)	Strong Argument (Strong)	Weak Argument (Weak)	Strong Argument (Strong)	Weak Argument (Weak)
Report = "True"	1	0.5	0.5	0	0	0.5	0.5	1

Table 2: Conditional probability table.

Results

Belief change is calculated as the degree to which people move from the prior (assumed to be 0.5). Table 3 list these.

Elaboration	Source Reliability	Argument Quality	Mean Belief Change	Standard deviation
Low	Unreliable	Weak	-0.21	0.24
		Strong	-0.09	0.30
	Reliable	Weak	0.25	0.23
		Strong	0.37	0.15
High	Unreliable	Weak	-0.23	0.20
		Strong	-0.14	0.24
	Reliable	Weak	0.14	0.19
		Strong	0.32	0.14

Table 3: Mean belief change for each condition.

To investigate how the variables functioned in influencing belief change (comparing whether their functions align more with the ELM and the BM), a 2x2x2 three-way mixed ANOVA was performed. A mixed linear regression model (lmer) was first fitted to the dataset. All main variables yield significant main effects. Argument Quality: $F = 97.17$, $p < .001$, Source Reliability: $F = 1111.60$, $p < .001$, and Elaboration: $F = 14.23$, $p < .001$.

Participants had more positive belief change for stronger arguments (M = 0.11, SD = 0.31) than weaker arguments (M = -0.01, SD = 0.30). Reliable sources (M = 0.26, SD = 0.20) also generated more positive belief change than unreliable sources (M = -0.17, SD = 0.25). At first sight, in the mixed ANOVA, there appeared to be significant differences in the degree of belief change between the high elaboration group (M = 0.02, SD = 0.29) and the low elaboration group (M = 0.08, SD = 0.33). However, the equivalent lmer showed the effect to be insignificant ($p = .56$)

Looking at the effect sizes of the variables, Argument Quality ($F = 97.17$) and Source Reliability ($F = 1111.60$) had much larger F-values than Elaboration ($F = 14.23$); suggesting the effect of Elaboration was negligible compared to the other two. Hence, when modelled altogether, Elaboration was not a main source of variation in the data and did not come up as a significant variable.

The effects of Source Reliability appeared stronger than that of Argument Quality – the former's effect size was larger

than the latter's; and the difference in degree of belief change between reliable and unreliable sources (difference = 0.44) was greater than that of between strong and weak arguments (difference = 0.13). There was a significant two-way interaction between argument quality and source reliability: $F = 4.37$, $p = .037$. However, what is more interesting is the three-way interaction between Argument Quality, Source Reliability, and Elaboration: $F = 3.97$, $p = .047$.

A post-hoc analysis was conducted to explore this three-way interaction – two separate two-way mixed ANOVAs (2 Argument Quality x 2 Source Reliability) were performed on each Elaboration group. Whilst both Argument Quality and Source Reliability had significant main effects in both Elaboration groups; the two-way interaction between the two variables was found significant for high Elaboration group: $F = 10.42$, $p = .0014$, but not for low Elaboration ($p = .95$).

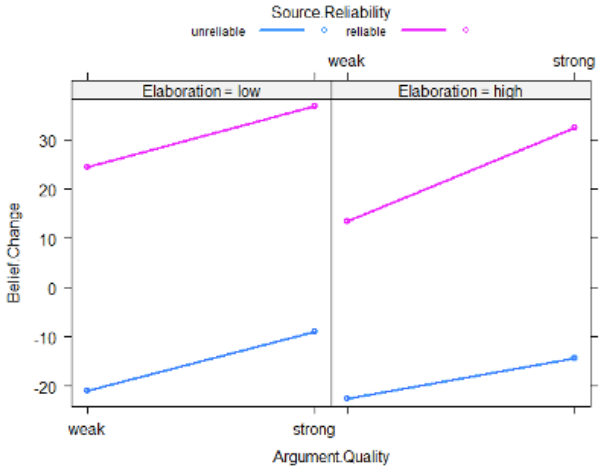

Figure 1: belief change for main experimental conditions

As shown in Figure 1, within the high elaboration group, for unreliable sources, the degree of belief change increases from -0.23 for weak arguments to 0.32 for strong arguments. The difference in degree of belief change between weak and strong arguments is greater for reliable sources (difference = 0.19) than for unreliable sources (difference = 0.08). This suggests that, in high elaboration, the two variables interact with each other – compared to the low elaboration group, there is an additional drop in degree of belief change for a strong argument from an unreliable source, and for a weak argument from a reliable source.

Finally, the three-way mixed model (Elaboration x Argument Quality x Source Reliability) yielded a R^2 of 0.56, suggested that the model accounted for 56% of the variation in the data. In excluding the Elaboration variable from the model, the two-way mixed model (Argument Quality x Source Reliability) yielded a similar R^2 of 0.55, which is just trivially smaller. This suggests that including the variable Elaboration in the model does not improve the fit of the model by much, which provides further support for our earlier speculation that Elaboration had negligible effects compared to the effects of the other two variables.

When looking at quantitative fit, we may compare Bayesian predictions with observed posteriors. A Spearman correlation show significant and positive correlation for these ($R^2 = 0.85$, $p < 0.001$). This suggests the BM enjoys a good fit with observed data.

Discussion

We hypothesized that the BM would have stronger explanatory power than the ELM, and that the functions of argument quality and source reliability observed in the data should align better with the BM predictions than the ELM predictions. Indeed, the current experiment results was found to be more congruent with the BM than with the ELM.

Corroborating Hypothesis 1, both argument quality effects and source reliability effects were found in both high and low elaboration conditions – elaboration did not interact with any of these main effects. Furthermore, the inclusion of the variable Elaboration in the model only helped account for an additional 1% (55% >> 56%) of the variation in the data, which suggests that elaboration likelihood only played a negligible role in the reasoning process.

These are contrary to the ELM's (Petty and Cacioppo, 1984) expectations of argument quality effecting only in high elaboration, and source reliability effecting only in low elaboration. As with other studies that failed to replicate the moderating effect of elaboration (e.g. Te'eni-Harari et al., 2007; Karson and Korgaonkar, 2001), the current study poses challenges to the validity of the ELM. We agree with Stiff's (1986) critique of the ELM's single-channel processing assumption, as well as SanJosé-Cabezudo et al.'s (2009) overturning of the ELM's trade-off postulate – argument and source can be processed simultaneously to jointly influence persuasion and belief change.

Although the ELM, arguably, does entertain the possibility of the multi-channel processing in special situations, such as when messages are ambiguous (e.g. Chaiken and Maheswaran, 1994); the current results suggest that multi-channel processing is not merely a possibility, but a norm under all conditions. As such, this provides strong support for the BM, which assumes both argument content and source reliability to always be integral to message convincingness (Hahn et al., 2009; Hahn et al., 2012).

Primacy of source: Interestingly, the study found source reliability to be more impactful than argument quality, which diverges from the BM's implicit assumption of an equal weight between the different variables (e.g. Hahn et al., 2009; Harris et al., 2015). This could be attributed to the design of our experimental materials, or it could also be a natural human predisposition to give more weight to source reliability.

However, we manipulated source reliability by including both trustworthiness and expertise elements in two separate statements, as compared to one single statement for the argument quality manipulation; hence, the source reliability effects may have been doubled. Furthermore, the last statement in the argumentation dialogue involved the expertise manipulation, so it could well be that participants were biased by the availability bias (also known as the recency effect) – the tendency to weigh recent events more heavily, because they are more readily to be recalled (Tversky and Kahneman, 1973).

On another hand, it is not implausible for argument quality to be inherently secondary to source reliability. In the social psychological study of trustworthiness (e.g. Fiske et al., 2006), the warmth dimension (i.e. perceived intent) is distinguished from the competence dimension (i.e. perceived ability). In discussing the primacy of the warmth dimension, Fiske et al. (2006, p. 77-79) suggested that people are cognitively more sensitive to warmth, so warmth is often assessed first and carries more weight.

Source reliability may also have such primacy over argument quality, and the stronger source effects observed in our data may be explained following the same logic – since the processing of source characteristics are less cognitively demanding, as the ELM suggested (Petty and Cacioppo, 1984); this might lead to people being more cognitive sensitive to source reliability, thereby giving more weight to it. More research is required to verify these speculations.

Argument and source: The two-way interaction between argument quality and source reliability was moderated by elaboration– as it was present in high elaboration conditions only. As such, Hypothesis 2 was partially confirmed.

In addition to positing that both argument content and source characteristics are integral to message convincingness, Bayesian researchers (e.g. Hahn et al., 2009) suggest the two variables have a bi-directional relationship and interact with each other. As Bovens and Hartmann (2003) and Hahn et al. (2012) explained, argument and source can be seen as possessing inferential values about each other, so people make inferences about the source from its argument quality, and vice versa. These propositions are not refuted by our findings, but further refinement on the BM may be required.

As previous Bayesian studies have not considered the role of elaboration, they may have failed to realise that the interactivity between argument and source, in fact, originates from participants being highly elaborated. It seems as if higher elaboration level increases one's propensity to think through the implications of argument quality and source reliability on each other – thereby leading to an additional drop in the convincingness of a strong argument from an unreliable source, and a weak argument from a reliable source.

Intriguingly, Petty and Cacioppo's (1981) concept of the elaboration continuum might be useful in unpacking why such interaction is only observed in high elaboration conditions. If we think of the act of undermining the strength of an argument due to its unreliability or undermining the reliability of a source due to its weak argument quality, as taking an extra step beyond simply adopting both information and adding them up; it makes sense that such act requires extra cognitive effort. Therefore, it is only when one is highly motivated/able, then they would devote great cognitive effort to consider diligently the bi- directional relationship between the argument and the source, and make additional inferences about each other; whilst when one is lowly motivated/able, they would not have the cognitive capacity to do so. It is entirely plausible that elaboration plays argument processing, but in a different manner assumed by the ELM.

The comparison in the present paper is limited by the fact that the Bayesian model is formally expressed while the ELM predictions are qualitative and descriptive. In future work, it would be relevant to approximate a formal expression of the ELM model to get quantitative instead of intuitive predictions for this approach, as this would yield cleaner comparisons between model predictions. Yet, we note that the intuitions from the ELM are not supported by the results, suggesting that a formal version would also struggle to account for the observed results.

Concluding remarks

In this paper, we provide a direct comparison between ELM and BM predictions. By manipulating high and low values for motivation/ability to elaborate, argument strength, and the trustworthiness/expertise of the source, we used dialogues to compare model predictions with observed posteriors. We find strong support for the Bayesian approach while we find little support for the ELM approach. Of course, there are several limitations to the current study. For example, the same design should be conducted with different materials to test if the experiment replicates. Further, reading dialogues of 3rd-person protagonists may not be an ideal manipulation of elaboration. Therefore, other ways of eliciting posteriors and manipulate the key variables should be trialed. However, we believe the study offers key insights into the appropriateness of competing modelling approaches to the psychology of reasoning and argumentation.

References

Alba, J. W., & Hutchinson, J. W. (1987). Dimensions of consumer expertise. *Journal of Consumer Research*, *13*(4), 411-454

Bitner, M. J., & Obermiller, C. (1985). The elaboration likelihood model: Limitations and extensions in marketing. *Advances in Consumer Research*, *12*(1), 420-425

Bovens, L., & Hartmann, S. (2003). *Bayesian epistemology*. Oxford University Press

Chaiken, S., & Maheswaran, D. (1994). Heuristic processing can bias systematic processing: Effects of source credibility, argument ambiguity, and task importance on attitude judgment. *Journal of Personality and Social Psychology*, *66*(3), 460-473

Cialdini, R. B., Petty, R. E., & Cacioppo, J. T. (1981). Attitude and attitude change. *Annual Review of Psychology*, *32*(3), 231-236

Chmielewski, T. L. (2012). Applying the Elaboration Likelihood Model to voting. The International Journal of Interdisciplinary Social Sciences. *Annual Review*, *6*(10). 33-48

Cook, T. D., & Flay, B. R. (1978). The persistence of experimentally induced attitude change. *Advances in Experimental Social Psychology*, *11*(C), 1-57

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160

Fiske, S. T., Cuddy, A. J. C., & Glick, P. (2006). Universal dimensions of social cognition: warmth and competence. *Trends in Cognitive Sciences*. *11*(2), 77-83

Hahn, U., Harris, A. J. L., & Corner, A. (2009). Argument content and argument source: An exploration. *Informal Logic*, *29*(4). 337-367

Hahn, U., & Hornikx, J. (2016). A normative framework for argument quality: Argumentation schemes with a Bayesian foundation. *Synthese*, *193*(6), 1833-1873

Hahn, U. & Oaksford, M. (2007). The Rationality of Informal Argumentation: A Bayesian Approach to Reasoning Fallacies. *Psychological Review*, *114*(3), 704-732

Hahn, U., Oaksford, M., Harris, A. J. L. (2012). Testimony and argument: A Bayesian Perspective. In F. Zenker (Ed.), *Bayesian argumentation: The practical side of probability* (pp. 15–38). Springer Science + Business Media

Harris, A. J. L., Hahn, U., Madsen, J. K., & Hsu, A. S. (2015). The appeal to expert opinion: Quantitative support for a Bayesian network approach. *Cognitive Science*, *40*(6), 1-38

Harris, A. J. L., Hsu, A. S., & Madsen, J. K. (2012). Because Hitler did it! Quantitative tests of Bayesian argumentation using ad hominem. *Thinking & Reasoning*, *18*(3), 311-343

Heesacker, M. H., Petty, R. E., & Cacioppo, J. T. (1983). Field dependent and attitude change: Source credibility can alter persuasion by affecting message-relevant thinking. *Journal of Personality*, *51*(4), 653-666

Homer, P. M. (1990). The mediating role of attitude toward the ad: Some additional evidence. *Journal of Marketing Research*, *27*(1), 78-86

Johnson, H. H., & Scileppi, J. A. (1969). Effects of ego-involvement conditions on attitude change to high and low credibility communicators. *Journal of Personality and Social Psychology*. *13*(1), 31-36

Karaslaan, H., Hohenberger, A., Demir, H., Hall, S., & Oaksford, M. (2018). Cross-cultural differences in informal argumentation: Norms, inductive biases and evidentiality, *Journal of Cognition and Culture*, *18*(3-4), 358-389

Karson, E. J., & Korgaonkar, P. K. (2001). An experimental investigation of internet advertising and the elaboration likelihood model. *Journal of Current Issues and Research in Advertising*, *23*(2), 53-72

Kitchen, P, J., Kerr, G., Schultz, D. E., McColl, R., & Pals, H. (2014). The elaboration likelihood model: Review, critique and research agenda. *European Journal of Marketing*, *48*(11/12), 2033-2050

Kruglanski, A. W., & Van Lange, P. A. M. (2012). *Handbook of theories of social psychology* (pp. 224-245). Sage

Madsen, J. K. (2016) Trump supported it?! A Bayesian source credibility model applied to appeals to specific American presidential candidates' opinions, Papafragou, A., Grodner, D., Mirman, D., & Trueswell, J.C. (Eds.) *Proceedings of the 38th Annual Conference of the Cognitive Science Society*, Austin, TX: Cognitive Science Society, 165-170

McGuire, W. J. (1969). The nature of attitudes and attitude change. In G. Lindzey & E. Aronson (Eds.), *The handbook of social psychology* (2nd ed., Vol. 3) (pp. 136-314). Addison-Wesley

Oaksford, M., & Chater, N. (2007). *Bayesian rationality: The probabilistic approach to human reasoning*. Oxford University Press

Oaksford, M., & Hahn, U. (2004). A Bayesian approach to the argument from ignorance, *Canadian Journal of Experimental Psychology*, *58*(2), 121-131

Petty, R. E., & Cacioppo, J. T. (1981). *Attitudes and persuasion: Classic and contemporary approaches*. Wm. C. Brown Company Publishers

Petty, R. E., & Cacioppo, J. T. (1983). Central and peripheral routes to persuasion: Application to advertising. In L. Percy & A. Woodside (Eds.), *Advertising and consumer psychology* (pp. 3–23). D. C. Heath and Company

Petty, R. E., & Cacioppo, J. T. (1984). Source factors and the elaboration likelihood model of persuasion. *Advances in Consumer Research, 11*(1), 668–672

Petty, R. E., & Cacioppo, J. T. (1986a). The elaboration likelihood model of persuasion. In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology* (Vol. 19, pp. 123– 205). Academic Press

Petty, R. E., & Cacioppo, J. T. (1986b). *Communication and persuasion: Central and peripheral routes to attitude change*. Springer-Verlag

Petty, R. E., Cacioppo, J. T., & Goldman, R. (1981). Personal involvement as a determinant of argument-based persuasion. *Journal of Personality and Social Psychology*, *41*(5), 847-855

SanJosé-Cabezudo, R., Gutiérrez-Arranz, A. M., & Gutiérrez-Cillán, J. (2009). The combined influence of central and peripheral routes in the online persuasion process. *CyberPsychology & Behavior*, *12*(3), 299-308

Schumann, D. W., Petty, R. E., & Clemons, D. S. (1990). Predicting the effectiveness of different strategies of advertising variation: A test of the repetition-variation hypotheses. *Journal of Consumer Research*, *17*(2), 192-202

Stiff, J. B. (1986). Cognitive processing of persuasive message cues: A meta-analytic review of the effects of supporting information on attitudes. *Communication Monographs*, *53*(1), 75-89

Te'eni-Harari, T., Lampert, S. I., Lehman-Wilzig, S. (2007). Information processing of advertising among young people: The elaboration likelihood model as applied to youth. *Journal of Advertising Research*, *47*(3), 326-340

Tenenbaum, J. B., Kemp, C., Griffiths, T. L., Goodman, N. D. (2011). How to grow a mind: Statistics, structure, and abstraction. *Science*, *313*(1279), 1279-1285

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, *5*(2), 207-232

Zhang, Y., & Buda, R. (1999). Moderating effects of need for cognition on responses to positively versus negatively framed advertising messages. *Journal of Advertising*, *28*, 1-15