Original Articles

A 'curse of knowledge' in the absence of knowledge? People misattribute fluency when judging how common knowledge is among their peers

Susan A.J. Birch[a],[*], Patricia E. Brosseau-Liard[b],[1], Taeh Haddock[a], Siba E. Ghrear[a]

[a] *The University of British Columbia, Canada*
[b] *University of Ottawa, Canada*

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ABSTRACT

Knowledge can be a curse: Once we have acquired a particular item of knowledge it tends to bias, or contaminate, our ability to reason about a less informed perspective (referred to as the 'curse of knowledge' or 'hindsight bias'). The mechanisms underlying the curse of knowledge bias are a matter of great import and debate. We highlight two mechanisms that have been proposed to underlie this bias—inhibition and fluency misattribution. Explanations that involve inhibition argue that people have difficulty fully inhibiting or suppressing the *content* of their knowledge when trying to reason about a less informed perspective. Explanations that involve fluency misattribution focus on the feelings of fluency with which the information comes to mind and the tendency to misattribute the subjective feelings of fluency associated with familiar items to the objective ease or foreseeability of that information. Three experiments with a total of 359 undergraduate students provide the first evidence that fluency misattribution processes are *sufficient* to induce the curse of knowledge bias. These results add to the literature on the many manifestations of the curse of knowledge bias and the many types of source misattributions, by revealing their role in people's judgements of how common, or widespread, one's knowledge is. The implications of these results for cognitive science and social cognition are discussed.

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1. Introduction

As scientists and educators it is easy to embrace the old adage 'knowledge is power'. After all, the merits of increases in knowledge are plentiful and obvious. Perhaps less obvious is the fact that knowledge can also be a curse, especially when it comes to perspective-taking: Once we have acquired a particular item of knowledge that knowledge tends to bias, or contaminate, our ability to reason about a more naïve perspective. For instance, people who know the meaning of an idiom (Keysar & Bly, 1995), whether or not a statement is sarcastic (Keysar, 1994) or the outcome of an election or other event (e.g., Fischhoff, 1975) are biased in the direction of *what they currently know* when assessing the judgments of someone less informed (for reviews see Blank, Musch, & Pohl, 2007; Ghrear, Bernstein, & Birch, 2016; Hawkins & Hastie, 1990).

As another example, economists Camerer, Lowenstein, and Weber (1989) were interested in whether sales agents who were better informed about their products than other agents might be at a disadvantage when selling their products as a result of their privileged information. In one study, participants were provided with a company's earnings over a 10-year-period. 'Informed participants' were provided with information about the company's earnings for the following year. 'Uninformed participants' were not given that additional information. The informed participants were asked to predict what uninformed participants would estimate as the companies' earnings for the additional year, and in doing so failed to fully ignore their privileged information. That is, they were biased in their predictions—'cursed', so to speak, by the privileged knowledge they possessed.

This 'curse of knowledge' bias has received a variety of different names, depending in part on the discipline or context in which it has been examined, including 'hindsight bias' (e.g., Bernstein, Atance, Loftus, & Meltzoff, 2004; Fischhoff, 1975), the 'knew-it-all-along' effect (e.g., Fischhoff, 1977; Sutherland & Cimpian, 2015; Wood, 1978), 'the curse of expertise' (e.g., Hinds, 1999), 'adult egocentrism' (e.g., Kelley & Jacoby, 1996; Keysar, Lin, & Barr, 2003), 'epistemic egocentrism' (e.g., Royzman, Cassidy, & Baron, 2003) and 'reality bias' (e.g., Mitchell & Taylor, 1999). We believe each is a manifestation of, and can best be described as, the 'curse of knowledge bias' defined as *a tendency to be biased by one's current knowledge state when attempting to reason about a more naive perspective.* This biasing effect occurs regardless of whether the more naïve per-

* Corresponding author at: Department of Psychology, University of British Columbia, 2136 West Mall, Vancouver, BC V6T 1Z4, Canada.
Email address: sbirch@psych.ubc.ca (S.A.J. Birch)

spective is one's own earlier perspective (in hindsight) or someone else's (see Birch & Bernstein, 2007; Birch & Bloom, 2003). [2]

At first glance, the curse of knowledge might appear to have a negative connotation as it constrains our ability to make accurate inferences about the perspectives of other individuals; however, some researchers have suggested that the curse of knowledge is the by-product of an otherwise adaptive learning system (Hoffrage, Hertwig, & Gigerenzer, 2000; Henriksen & Kaplan, 2003). These researchers argue that our brains are geared toward *acquiring* knowledge (not ignoring it!) and readily integrate new information, or update old information. Although this routine updating may worsen perspective taking, it serves an adaptive function by keeping track of new events and focusing our cognitive resources towards the most up-to-date information.

Importantly, the curse of knowledge bias is a robust and widespread phenomenon that has been documented cross-culturally (Heine & Lehman, 1996; Pohl, Bender, & Lachmann, 2002). This bias occurs even after people have been explicitly warned to avoid it (Pohl & Hell, 1996), and persists even when people are educated about the phenomenon and provided with cash incentives to try to prevent it (Camerer et al., 1989). Given the regularity with which we must gauge what others know, the bias frequently crops up in many day-to-day conversations, as well as in written forms of communication (see Pinker, 2014). The curse-of-knowledge bias has been examined through a host of different experimental techniques and across a wide range of academic disciplines and real-world contexts, such as in medicine, law, education, business, politics, inter alia (e.g., Hinds, 1999; Keysar, 1994; Keysar & Bly, 1995; see Guilbault, Bryant, Brockway, & Posavac, 2004, and Hawkins & Hastie, 1990 for reviews).

Cognitive scientists and memory researchers typically investigate the curse of knowledge bias (often referred to as the hindsight bias in this discipline) using either a memory design or a hypothetical design (see Pohl, 2004). In a memory design, researchers ask participants to answer questions. Later, the participants learn the correct answers to the questions, and are asked to recall their original answers. Participants' recollection of their original answers tends to be biased toward the newly learned correct answers (e.g., Fischhoff & Beyth, 1975). In a hypothetical design, participants learn the answer to a question, and then estimate how another individual will respond, or how they *would have* answered the question if they had not been told the answer. For example, Fischhoff (1975) provided participants with descriptions of a historical event involving the war between the British and the Gurka. Some participants did not learn the war's outcome, whereas others did. Subsequently, participants had to consider several possible outcomes, including the actual outcome. For each possible outcome, participants estimated how likely it would be for a naïve peer to predict that outcome. Compared to participants who did not

know the true outcome, knowledgeable participants overestimated the likelihood that a naïve peer could predict the outcome.

There is a wealth of psychological literature on the curse of knowledge in adults and its effects on different aspects of memory and social cognition (see e.g., Lilienfeld, Amirati, & Landfield, 2009; Roese & Vohs, 2012). Despite the extensive research on this bias in adults, comparatively few studies have examined this bias in children. Nonetheless, researchers have shown that young children are more susceptible to this bias than older children and adults (Birch & Bloom, 2003; Bernstein, Erdfelder, Meltzoff, Peria, & Loftus, 2011; Bernstein, Atance, Meltzoff, & Loftus, 2007) and have argued that the exaggerated form of this bias may account, at least in part, for young children's deficits in their ability to reason about false beliefs in the classic false belief or 'theory of mind' tasks (see Bernstein et al., 2004; Bernstein et al., 2007; Birch, 2005; Birch & Bernstein, 2007; Birch & Bloom, 2003; Birch & Bloom, 2004; Birch & Bloom, 2007; Ghrear et al., 2016; Mitchell & Taylor, 1999; for a recent review see Birch et al., 2017). This bias also appears to contribute to children's difficulties with source monitoring and source memory recall (see e.g., Gopnik & Graf, 1988; Sutherland & Cimpian, 2015; Taylor, Esbensen, & Bennett, 1994) .

1.1. Potential mechanisms underlying the curse of knowledge bias

Despite an abundance of evidence showing the widespread impact of this bias in a variety of contexts, there is comparatively little known about the specific mechanisms that contribute to the curse of knowledge bias. Several researchers have proposed factors that may influence the bias, such as individual differences in working memory and intelligence (e.g., Coolin, Erdfelder, Bernstein, Thornton, & Thornton, 2015; ; Musch & Wagner, 2007), source monitoring abilities (e.g., Birch, 2005; Birch & Bernstein, 2007) and the extent to which the outcome information 'makes sense' or is surprising (e.g., Konečný & Bačová, 2012; Pezzo, 2010; Pohl et al., 2002), just to name a few (see also Fischhoff, 1977; Harley, Carlsen, & Loftus, 2004; Nestler, Blank, & Egloff, 2010; Pohl, Eisenhauer, & Hardt, 2003; Sanna & Schwarz, 2004 and the 'General Discussion' section). Still, the exact nature of the mechanisms underlying the curse of knowledge bias is a matter of immense interest and discussion (e.g., Groβ & Bayen, 2015a; Groβ & Bayen, 2015b). Identification of the mechanisms underlying this bias will advance our understanding of how people reason about others' knowledge and shed light on how to craft more effective de-biasing techniques to reduce the curse of knowledge bias and improve our memory and perspective taking abilities.

One proposed mechanism underlying the curse of knowledge bias is Inhibitory Control (IC). Explanations that involve inhibition argue that people have difficulty fully discounting or inhibiting their own knowledge (see Bayen, Pohl, Erdfelder, & Auer, 2007; Groβ & Bayen, 2015b; Pohl et al., 2003; Lagattuta, Sayfan, & Blattman, 2010; Lagattuta, Sayfan, & Harvey, 2014). For example, when people are asked trivia questions such as "Where is the Trevi Fountain?" and are asked to estimate the percentage of peers who know the answer to this question, those who know the answer (i.e., Rome, Italy) overestimate the percentage of their peers who will know the answer compared to participants who do not know the answer. That is, individuals who know where the Trevi Fountain is are not able to completely ignore this information when trying to gauge a more naïve perspective. A strength of the inhibition explanation is its potential to explain the U-shaped pattern of age-related changes in which the magnitude of the curse of knowledge bias is greater in younger children and older adults than it is in older children and young adults (Bayen et al.,

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[2] We favor the term 'curse of knowledge' over the term 'hindsight bias' because the bias is not limited to recollections made in hindsight but applies more generally to any attempt to reason about a less informed perspective than one's current perspective. We also favor the term 'curse of knowledge' over terms that use the word 'egocentrism' because the bias appears to be asymmetrical in nature (i.e., there does not appear to be an equivalent 'curse of ignorance') suggesting it is not purely due to a difficulty taking *any* perspective other than one's own (see e.g., Birch & Bloom, 2003; Nickerson, Baddeley, & Freeman, 1987). Finally, we favor the term 'curse of knowledge' over 'reality bias' because the former captures the fact that it is one's knowledge or beliefs about reality (and not necessarily reality per se) that leads to the bias—that is, one can be biased by what one *thinks* they know about reality (such as whether a statement was intended to be sarcastic or not) even if what one thinks is incorrect.

2006; Bernstein et al., 2011; Groß & Bayen, 2015b). This U-shaped developmental trajectory is consistent with the fact that inhibitory processes are tied with frontal lobe development, and the frontal lobes are the last part of the brain to develop and the first part to show signs of deterioration in older adults (Dempster & Corkhill, 1999). Both Coolin, Erdfelder, Bernstein, Thornton, and Thornton (2014) and Groß and Bayen (2015b) found evidence in support of an inhibition explanation; however, age differences in inhibitory function could not fully account for the age differences these researchers observed in the bias, suggesting that more than one mechanism is likely involved (see Bayen et al., 2007 for a review of the strengths and weaknesses of inhibition accounts).

Fluency Misattribution (FM) has been proposed as another potential mechanism behind the curse of knowledge bias (Harley et al., 2004). According to an FM explanation it is not a difficulty inhibiting the *content* of the knowledge that leads to the bias, but rather it is the fluency (or ease) with which that content comes to mind (or the sense of fluency associated with that information) that gets misattributed to the information being easier or more foreseeable than it really is. To illustrate, recall the example above: when people are given trivia questions such as "Where is the Trevi Fountain?" and are asked to estimate the percentage of peers who will know the answer to this question, those who know the answer overestimate the percentage of peers who will also know (i.e., an example of the curse of knowledge bias). According to a fluency misattribution explanation it is not (or not just) a difficulty discounting the content of the knowledge (Rome, Italy) that results in the bias, but rather it is the fluency with which that content comes to mind that gets misattributed or misinterpreted. The exact nature of the misattribution may vary—it may lead one to misattribute how common that information is, or how easy it might be to infer or foresee, but it is considered a *mis*attribution because a correct attribution would involve recognizing that the ease with which the information came to mind is due to something other than its objective ease or foreseeability (e.g., its due to one's prior exposure to that information).

An FM explanation of the curse of knowledge bias is consistent with a large body of work showing that when *any* part of one's processing of a stimulus is fluent (i.e., processed quickly or easily), that person can misattribute the *source* of that fluency. One's processing fluency has been manipulated in various ways in the literature, for example, through the perceptual clarity or readability of the information (e.g., by manipulating the font the material is presented in; see Shah & Oppenheimer, 2006; Song & Schwarz, 2008) or through prior exposure or repetition of the information. For instance, the feelings of fluency associated with quick and easy stimulus processing can lead participants to conclude that they like a familiar stimulus more than they like an unfamiliar stimulus because unfamiliar stimuli are processed less fluently (a specific type of fluency misattribution phenomenon referred to as the 'mere exposure effect', Zajonc, 1968). FM has also been shown to influence judgments of whether a stimulus was seen before (e.g. Jacoby & Whitehouse, 1989) as well as judgments about a stimulus's clarity, truth value, duration, and level of fame (e.g., Bernstein, Whittlesea, & Loftus, 2002; Briñol, Petty, & Tormala, 2006; Jacoby, Woloshyn, & Kelley, 1989; Unkelbach, 2006; Winkielman, Schwarz, Reber, & Fazendeiro, 2003), providing evidence that people use the relative ease of their information processing experience to make all sorts of cognitive, perceptual, and affective judgments (see e.g., Chen & Sakamoto, 2016; Geurten, Lloyd, & Willems, 2016; Higham, Neil, & Bernstein, 2017; Joye, Steg, Ünal, & Pals, 2016; Lanska, Olds, & Westerman, 2013; Olds & Westerman, 2012; Wang, Brashier, Wing, Marsh, & Cabeza, 2016).

One experiment by Harley et al. (2004; Exp. 3) demonstrated the impact of fluency misattribution on the curse of knowledge specifically. Participants were presented with pictures of celebrity faces at varying degrees of perceptual clarity. They first showed participants an 'outcome stimulus' (i.e., an unfiltered, clear, image of a celebrity face such as Harrison Ford) followed by a degraded unrecognizable image of that same face that gradually became clearer with time. Participants were asked to stop the clarification process when they thought that a naïve peer, someone who had not seen the initial clear image, would first be able to identify the celebrity. Critically, some of the initial images were 'new' to participants (i.e., they had not seen those specific images prior to being asked to estimate when a peer could identify them), whereas, some of the images were 'old' and would be processed more fluently because they were presented before. The results demonstrated that participants believed that their peers would identify the faces at a more degraded point than the participants themselves were able to at baseline, and, importantly, this effect was greater for old faces than for new faces. That is, the curse of knowledge bias was greater for more fluently-processed items suggesting that a FM mechanism may contribute to the bias, at least in a visual perception task (see also Bernstein & Harley, 2007; see below for an alternative explanation).

The primary distinction between an inhibition mechanism and a fluency misattribution mechanism centers around whether the curse of knowledge bias stems from a failure to fully inhibit the specific *content* of one's knowledge or from a failure to correctly attribute the sense of *fluency* associated with easy to process information (e.g., familiar information). However, in most real-world situations, and in the Harley et al. (2004) task, any effects resulting from inhibitory difficulties or fluency misattributions may be naturally confounded. For instance, a teacher might assume her students will know the capital of France both because she knows the answer (and cannot fully inhibit 'Paris') *and* because Paris comes to mind quickly and easily. As such, completely dissociating the impact of having to inhibit content knowledge, versus having to discount the ease with which the information comes to mind, is a difficult enterprise. Take even Harley et al.'s (2004) clever design mentioned above for instance: given that the more frequently information is encountered the more difficult it is to inhibit (i.e., it becomes more salient and cognitively entrenched), it is not possible to ascertain definitively whether the larger bias found for more familiar items is due to a) the increased difficulty inhibiting the more salient 'old' information, b) one's tendency to misattribute the greater ease with which one recognized the celebrity that was presented most frequently, or c) some combination of the two. Consequently, whether fluency misattribution is ever *sufficient* to independently contribute to the curse of knowledge remains an open question.

1.2. The current research

The three experiments outlined within this paper were designed to fill this gap in the literature by testing whether fluency misattribution (in the absence of any knowledge to inhibit) can independently contribute to the curse of knowledge bias. That is, we asked whether a curse of knowledge bias can, ironically, occur even in the *absence of knowledge*. Importantly, the present studies are not designed to test whether fluency misattribution or inhibition is the primary mechanism underlying the curse of knowledge: Indeed, we suspect that both of these mechanisms contribute to the bias. Rather the current studies were designed to provide a hard test of whether fluency misattribution can be *sufficient* to induce the bias. In doing so, we also add to a body of literature on the various types of judgments affected by flu-

ency misattribution—in this case the impact fluency misattribution processes have on people's judgments of how common specific factual information is among their peers. This work also contributes to a body of literature revealing the many *manifestations* of the curse of knowledge. A wealth of previous research has shown how the curse of knowledge can (1) bias people's recollections of what they once knew and (2) bias people's ability to infer what someone else (e.g., a peer) will think, but comparatively little research has examined (3) how the bias affects people's judgments of how common, or widespread, their knowledge is (but see Fussell & Krauss, 1992; Nickerson et al., 1987). The current study examined this third manifestation of the curse of knowledge bias in people's judgments of how common factual knowledge is among their peers. Here, undergraduate participants were presented with lists of trivia questions about word meanings and facts and asked to judge the percentage of their peers who would know the answers (whereby 'peers' referred to other psychology students enrolled in the study).

As mentioned above, a person's content knowledge and the fluency with which their content knowledge comes to mind (or with which they process a stimulus) are often naturally confounded. In order to disentangle the effects of content knowledge and fluency, we therefore relied on two different types of situations where participants' content knowledge would be absent but their stimulus processing would be fluent: Previously learned but subsequently forgotten information (Experiments 1 and 2) and exposure to questions in the absence of the answers (Experiment 3).

2. Experiment 1

In Experiment 1, undergraduates were taught the meaning of unfamiliar vocabulary words and the answers to various trivia facts. Participants were then asked to estimate the percentage of their peers who will know the answers. We experimentally manipulated the knowledge of participants (i.e., by teaching them the answers to some items and not others) rather than relying on naturally-occurring, a priori, differences in knowledge. This manipulation was critical for equating participants' level of familiarity with the items (i.e., all known items should be equally familiar because they learned them during our experiment). We also manipulated the time delay between when participants learned the items and when they made their peer estimates (immediately vs. one week later). The time delay naturally led to some of the answers being forgotten, thereby allowing us to compare three conditions of interest: the Known Condition (i.e., items participants were taught and remembered; knowledge present and fluency present) and the Unknown Condition (items participants did not know; knowledge absent and fluency absent) as well as a third condition naturally created by the process of forgetting—the Fluency Condition (items that participants were taught but had forgotten; items that should be fluently processed because of prior exposure but the content is explicitly unavailable, i.e. knowledge absent but fluency present).

Participants were asked to estimate how many of their peers would know the answer to each question (henceforth referred to as their 'peer estimates') regardless of whether or not the participants themselves knew the answer. We hypothesized that participants would show the curse of knowledge bias in their judgments of how common, or widespread, their knowledge is. That is, they would make higher peer estimates in the Known Condition (for known items) than in the Unknown Condition (for unknown items). More importantly, comparisons of the peer estimates in the Unknown Condition with those in the Fluency Condition allowed us to examine the unique contribution of fluency misattribution in the absence of knowledge.

2.1. Method

2.1.1. Participants

One hundred and eight participants were recruited from undergraduate psychology classes and received extra credit toward one psychology class for their participation. Data from 20 additional participants were not included in the analyses because of experimenter error (6), or the participant's failure to comply with instructions or complete enough questions for analyses (14; these were primarily participants who failed to provide any peer estimates for the items they did not know).

2.1.2. Materials

Two sets of learning materials were constructed (Sets A and B), each consisting of 9 obscure vocabulary words with definitions and 9 obscure factual questions with answers (see Appendix A). Obscure items were selected so that participants would be unlikely to know the material beforehand, thus allowing for experimental manipulation of their knowledge. Twenty-four additional items of easy to medium difficulty were used as filler items in the Test Phase for the sole purpose of providing a range of difficulty in the items such that participants would not simply give low estimates of peers' knowledge across the board.

2.1.3. Procedure

Participants were invited to the lab for either a single visit (Time Delay: Immediate) or two visits one week apart (Time Delay: One Week). When participants first arrived at the lab, they were administered Part 1 of the experiment, which consisted of a Learning Phase followed by an unrelated filler task. During the learning phase, participants were presented with either item set A or B. Each set consisted of "Word" items, where participants were given a vocabulary word and asked for the definition, and "Fact" items, where participants were asked the answer to a trivia question. The order of these two types of items alternated between participants (Order: Words First or Order: Facts First). Participants were asked to learn all 18 items and immediately tested on their learning. Participants were told that they would be tested on their memory of these items, however no incentive was provided for successfully remembering the items. Part 1 ended with a filler task to provide a short delay for those going on to Part 2 immediately.

Part 2, the Test Phase, was then administered either immediately or one week later, based on random assignment. In the Test Phase, participants were told that 100 other psychology students would be quizzed on their knowledge of the same words and facts but without the benefit of the Learning Phase that they went through. For each item, participants indicated their answer if they knew it and were instructed not to guess but to leave it blank if they did not know it. For each item, participants were also asked to estimate the percentage of other students in the study who would know the answer (i.e., their 'peer estimates').

2.2. Results

2.2.1. Coding and analyses

Participants' answers for each question in the Test Phase were categorized as correct, incorrect, or unknown. Participants' peer estimates on each item served as the dependent variables for all analyses. For each participant, items that were taught and that the participant

remembered were classified as "known" items, items that were taught but forgotten at test were classified as "fluent", and items that were not taught and were unknown to participants were classified as "unknown". All other items (i.e., items that a participant answered wrong[3], and items that were not taught but that the participant knew) were disregarded. Participants' peer estimates for filler items were not of interest herein and therefore excluded from analyses. Table 1 shows descriptive statistics across all obtained estimates, both across all scores and split by Time Delay condition.

Given our experimental design, peer estimates for all items are not strictly independent data points: There are likely similarities between peer estimates within participants (i.e., some individuals likely tend to give higher estimates on average and some likely tend to give lower estimates on average) as well as within items (i.e., some items are likely to be perceived as more widely known than others). In order to account for these dependencies, obtained estimates were analysed with cross-classified random effects models, with obtained estimates cross-classified by participant and by item. Three separate analyses were run: One comparing Known versus New items (testing the traditional "curse of knowledge"), one comparing Known versus Fluent items (testing the effect of content knowledge holding fluency constant), and one comparing Fluent versus Unknown items (testing the effect of item fluency holding content knowledge constant). All analyses were run with HLM7 using maximum likelihood (ML) estimation, and all converged within 5 or fewer iterations. For all three analyses, the between-participants factor of time delay (immediate vs. one week) was included both to test its effect on the overall mean estimate and on the knowledge slopes. Preliminary analyses also included item-level variables of set (does the item come from list A or list B) and item type (word or fact item) but these were not found to significantly influence either the intercepts or the knowledge slopes of any of the three models, and excluding these factors did not result in a significant change in the log likelihood for any of the three models (all $\chi^2(4) < 3.06$, all ps > 0.50). The between-participants variable of Order (i.e. whether participants were presented with words first or facts first) did however show significant effects on some of the intercepts and knowledge slopes, and was therefore kept as part of the analyses, even though it was not a factor that was originally of theoretical interest. The coefficients and statistical tests for these three analyses are presented in Table 2.

2.2.2. Curse of knowledge (Comparing Known vs. Unknown items)

A cross-classified random effects model was used to calculate the effect of knowledge (coded as −1 for Unknown and +1 for Known) on participants' estimates of others' knowledge, as well as the influence of Time Delay (coded as −1 for immediate and +1 for one-week delay) and Order (coded as −1 for Words First and +1 for Facts First) on both the mean estimates and on the effect of knowledge. Neither Time Delay nor Order significantly affected the overall mean peer estimates of participants. The significant positive knowledge slope indicates that Knowledge had a significant effect on participants' peer estimates: Participants estimated that an additional 8.55 out of 100

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[3] Interestingly, one might expect that participants' peer estimates would be similar for items that the participants knew and items that the participants *thought* they knew (i.e., wrong items). This is supported by the data: Of all the participants included in Study 1, 95 had a score for at least one known and one wrong item. Averaging across known and wrong items for these participants, the mean estimate of others' knowledge was 50.1% for known and 52.9% for wrong items. This difference was not statistically significant, $t(94) = 1.58$, $p = 0.117$. That is, whether you correctly know the answer to a question or only think you know, you tend to overestimate the percentage of your peers who will share your perspective.

Table 1

Means, standard deviations, and number of estimates by knowledge category and time delay condition.

		Known	Fluent	Unknown
Overall	*M*	**42.0**	**38.0**	**34.1**
	SD	26.7	23.6	22.7
	N	1286	503	1527
Time Delay: Immediate	*M*	**37.8**	**35.2**	**32.6**
	SD	26.4	26.2	23.5
	N	833	112	786
Time Delay: One week	*M*	**49.6**	**38.8**	**35.7**
	SD	25.7	22.8	21.6
	N	453	391	741

peers would know the "Known" items than the "Unknown" items, thus demonstrating the typical "curse of knowledge" effect. As expected, this effect of knowledge interacted significantly with Time Delay, with the effect of knowledge significantly greater for one-week-delay participants (estimated difference: 12.75/100) than those tested immediately (estimated difference: 4.64/100). Unexpectedly, Knowledge also significantly interacted with Order: The difference between Known and Unknown items was estimated as larger for participants who were presented with words first (estimated difference: 9.78) than facts first (estimated difference: 7.36).

2.2.3. Effect of content knowledge (Comparing Known vs. Fluent estimates)

A cross-classified random effects model was used to calculate the effect of content knowledge (coded as −1 for Fluent and +1 for Known), as well as the influence of Time Delay and Order (both coded in the same way as in the previous analysis). The significant positive content knowledge slope indicates that Content Knowledge influenced participants' peer estimates: Participants estimated that an additional 7.28 out of 100 peers would know the "Known" items than the "Fluent" items. Contrary to the previous analysis, interactions between content knowledge and time delay as well as between content knowledge and order were not significant. Order did not significantly affect the overall mean estimate of participants, but Time Delay did: Across both types of items, participants estimated that 9.03 out of 100 more peers would know the average item if they were asked after a one-week delay than immediately.

2.2.4. Effect of fluency (Comparing Fluent vs. Unknown items)

A cross-classified random effects model was used to calculate the effect of fluency (coded as −1 for Unknown and +1 for Fluent), as well as the influence of Time Delay and Order (both coded in the same way as in the previous analysis). Neither Time Delay nor Order significantly affected the overall mean estimate of participants. Fluency had a significant effect on participants' estimates: Participants estimated that an additional 1.87 out of 100 peers would know the "Fluent" items than the "Unknown" items. Note that the effect of Fluency, though statistically significant, is much smaller in size than the effect of Content Knowledge obtained in the previous analysis. Fluency did not interact significantly with Time Delay. Unexpectedly, Fluency significantly interacted with Order: The difference between Fluent and Unknown items was larger for participants who were presented with words first (estimated difference: 3.66/100) than facts first (estimated difference: 0.14/100).

2.3. Discussion

Taken together the findings from Experiment 1 demonstrate that a curse of knowledge bias is present in university students' estimates of

Table 2
Experiment 1: Fixed effects parameter estimates and significance tests for models testing the curse of knowledge, the effect of content knowledge, and the effect of fluency.

	Effect	Coefficient	S.E.	t	Approx. df	P
	Intercept					
Curse of knowledge (Comparing Known and Unknown items)	INTERCEPT	39.08	2.04			
	ORDER	−2.57	1.71	−1.50	106	0.136
	TIME DELAY	3.04	1.71	1.78	106	0.079
	Slope					
	KNOWLEDGE	4.27	0.31	13.68	2667	<0.001*
	ORDER*KNOWLEDGE	−0.60	0.30	−2.02	2667	0.044*
	TIME DELAY*KNOWLEDGE	2.03	0.31	6.61	2667	<0.001*
	Intercept					
Effect of content knowledge (Comparing Known and Fluent Items)	INTERCEPT	41.80	2.22			
	ORDER	−3.52	1.87	−1.88	106	0.063
	TIME DELAY	4.51	1.88	2.40	106	0.018*
	Slope					
	CONTENT	3.64	0.58	6.24	1643	<0.001*
	ORDER*CONTENT	0.78	0.47	1.67	1643	0.095
	TIME DELAY*CONTENT	0.97	0.51	1.92	1643	0.055
	Intercept					
Effect of fluency (Comparing Fluent and Unknown items)	INTERCEPT	35.28	1.97			
	ORDER	−2.34	1.71	−1.37	106	0.173
	TIME DELAY	1.47	1.71	0.86	106	0.393
	Slope					
	FLUENCY	0.93	0.44	2.12	1884	0.035*
	ORDER*FLUENCY	−0.88	0.37	−2.39	1884	0.017*
	TIME DELAY*FLUENCY	0.47	0.42	1.10	1884	0.271

* p < .05. Note: All factors centered at the grand mean.

their peers' knowledge even for recently learned and relatively obscure vocabulary words and trivia facts. Moreover, the curse of knowledge bias was larger after a one-week delay than after a brief delay of only a few minutes, suggesting that the mechanisms contributing the curse of knowledge are influenced by the passage of time. This finding is consistent with the notion that fluency *mis*attribution only occurs, or occurs to a greater extent, when the *source* of the fluency has been forgotten (Jacoby et al., 1989).

Of particular interest, this experiment provided the first evidence of the independent contribution of fluency misattributions to the curse of knowledge bias. The present study found evidence that both content knowledge and fluency can independently contribute to the curse of knowledge bias. In addition, it provides the first evidence, to our knowledge, that fluency misattribution alone can influence judgements of how widely known information is among one's peers.

A potential limitation of Experiment 1 was the low rate of forgetting, that resulted in a reduced sample size (and power) to test the effect of fluency misattribution. We therefore conducted a second experiment, increasing the time delay between learning and test to two weeks (and eliminating the Time Delay: Immediate condition) to allow for a higher rate of forgetting.

3. Experiment 2

3.1. Method

3.1.1. Participants

One hundred seven undergraduate students enrolled in a university psychology course participated in this experiment. Twenty-one additional participants were recruited but eliminated: 12 failed to complete Part 2; six failed a crucial pre-test question (explained below); one gave nonsensical answers (i.e., repeatedly giving percentages above 100); and two remembered or claimed to remember every item in the list they learned, therefore their data could not be used to test either the effects of content knowledge or fluency.

3.1.2. Materials

Two new sets of 9 obscure words and 9 obscure facts were created for this experiment (see Appendix A). We used new lists of items to ensure our findings were not specific to the particular items chosen in Experiment 1 but would replicate across a variety of items. Twenty-four new filler questions were created for the Test Phase.

3.1.3. Procedure

The study was administered online, via a survey website. Participants signed up for a specific pair of study dates two weeks apart via an online registration system. On the first study date, participants were emailed a link to Part 1 of the study. Part 1 of the present experiment was similar in format to Part 1 of Experiment 1 detailed above, except that two new lists of 18 obscure items were created, and for half the participants the "Word" items were presented as definitions (i.e., participants were given the definition and asked for the word instead of the reverse – analyses of the effect of this particular factor are presented in the Supplemental Material). Which item set participants learned (Set A vs. B) and the order of the items (words vs. facts first) were counterbalanced. After being presented with 9 Word items and 9 Fact items (order counterbalanced) and asked to write down the answers if they knew them (in order to remove any items that participants were already familiar with even before the experiment began), participants were given the answers to the items and immediately tested on their learning. To end Part 1, participants then completed an additional questionnaire asking them to rate 'how familiar aiming to assess the perceived familiarity of the items presented in Experiment 1. This was done in order to answer a secondary question about the role of perceived familiarity on the size of the curse of knowledge (details and results are presented in the Supplemental Materials.)

Approximately two weeks later participants were sent the web link to the Test Phase. Apart from being administered online instead of in person, the procedure for Part 2 was the same as in Experiment 1.

3.2. Results

Estimates were classified as Known, Fluent or Unknown using the same criteria as in Experiment 1. Ninety-eight Known and 11 Fluent answers were discarded because participants already knew these items in Part 1 before being taught[4]. For the remaining items, Table 3 lists descriptive statistics.

As in Experiment 1, obtained estimates were analysed with 3 cross-classified random effects models, one testing the "curse of knowledge", one the effect of content knowledge and one the effect of fluency, with obtained estimates cross-classified by participant and by item. Preliminary analyses ruled out any main effect of item set or any interaction between Set and Knowledge; this variable was therefore excluded from final analyses. Contrary to Experiment 1, Order (words first or facts first) did not significantly influence any of the results, and was therefore also excluded from final analyses. Variables that were retained for all analyses were Item Type (word or fact), Word Format (whether word items were presented as definitions or as words), and the interaction between these two variables, given that any effect of Word Format should only be expected to influence answers on the Word items and not the Fact items. All analyses were run with HLM7 using ML estimation, and all converged within fewer than 8 iterations. Parameter estimates and significance tests are listed in Table 4.

Slopes for Knowledge, Content Knowledge and Fluency were all significant: Once again, we see that both content knowledge and fluency appear to influence participants' estimates of others' knowledge. However, the effect of content knowledge (participants estimated that 6.55 more peers would know the average "known" item than "fluent" item) is much larger than the effect of fluency (participants estimated that 2.26 more peers would know the average "fluent" item than the average "known" item).

Data from Experiment 2 allowed us to answer some additional questions about factors influencing the curse of knowledge: The effects of the format of word items, of individual differences in memory, and of item-specific ratings of familiarity. These analyses were exploratory and tangential to the main purpose of this research, therefore we present their results in the *Supplemental Materials* for interested readers.

3.3. Discussion

Experiment 2 replicated the findings of Experiment 1 with a new sample, a different set of items, and a longer time delay. Once again, participants' estimates of their peers' knowledge was greater for items they knew in comparison to items of similar difficulty that they did not know. Of particular interest, participants' estimates of their peers' knowledge was greater for items they had previously been taught but forgot, compared to new items that they had not been taught. That is, even when participants could not explicitly bring the content of their knowledge to mind, the sense of fluency associated with having been previously taught the information (and/or exposed to the question; see Exp. 3) was sufficient, in and of itself, to lead participants to inflate their estimates of what their peers would know. Hence, it appears that misattributions of the fluency associated with an item can independently contribute to one's tendency to overestimate others' knowledge.

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[4] Note that the analyses were repeated with these items included and the conclusions did not change substantially.

Table 3
Descriptive statistics for individual items by knowledge category for Experiment 2.

		Known	Fluent	Unknown
Overall	*M*	**31.5**	**25.9**	**24.1**
	SD	25.8	21.3	21.3
	N	517	1143	1694

Experiments 1 and 2 are not without limitations. We explicitly instructed participants not to guess if they were not sure of the answer to a question, thus we cannot rule out the possibility that participants had not completely forgotten the answer (e.g., in some cases, they may have had an inkling of the right answer, but professed ignorance because they were instructed not to guess). It is therefore possible that the difference in peer estimates between Fluent and Unknown items is the result of participants failing to inhibit some residual knowledge of the once-learned answer (or an answer they are uncertain of), rather than purely due to a misattribution of the fluency associated with the items. Thus, in Experiment 3 we examined whether an effect of fluency would emerge in the absence of having *ever* been exposed to the content. In other words, would mere exposure to a question (without exposure to the answer) be sufficient to inflate people's estimates of their peers' knowledge of the answer? This experimental manipulation also serves to rule out the possibility that the forgotten items in Experiments 1 and 2 were more difficult than other items and that it was the item difficulty, rather than the participants' feelings of fluency, that contributed to the effect.

4. Experiment 3

4.1. Method

4.1.1. Participants

One hundred and forty-four undergraduates enrolled in a psychology course completed this experiment. Thirty-six additional participants were recruited but their data were excluded because they failed to complete both experimental sessions (5) or failed to follow instructions, for example not completing the peer estimates (31).

4.1.2. Materials

Three new lists (labelled A, B and C) of 14 obscure trivia questions as well as 24 easy filler questions were created for this experiment (see Appendix A).

4.1.3. Procedure

This study was conducted as a web-based experiment similar to Experiment 2. In the Learning Phase, participants were given one of the 3 lists of trivia questions and their answers and were asked to memorize them. These items are referred to as the Known items. After participants acknowledged that they knew the answer to each, participants were presented with a second list of questions and were asked if they knew the answers, but *were not taught the answers*. These items are referred to as the Fluent items. Next, participants were exposed to both the Fluent and Known items (the questions only, not the answers, e.g., 'Who invented the television?') *three additional times* to increase the familiarity associated with the Fluent items (and to equate the number of exposures for the Known and Fluent items). In the Testing Phase, a week later, all participants were presented with 66 questions, including both lists they were presented with in the Learning Phase (Known and Fluent items), the third list (completely Unknown items), and filler items. For each question, they were asked whether they knew the answer (and to provide it if

Table 4
Experiment 2: Fixed effects parameter estimates and significance tests for models testing the curse of knowledge, the effect of content knowledge, and the effect of fluency.

	Effect	Coefficient	S.E.	t	Approx. df	P
Curse of knowledge (Comparing Known and Unknown items)	Intercept					
	MEAN ESTIMATE	26.46	1.78			
	WORD FORMAT	1.10	1.67	0.66	105	0.512
	ITEM TYPE	−0.75	0.69	−1.09	34	0.289
	WORD FORMAT*ITEM TYPE	1.50	0.31	4.79	2063	<0.001*
	Slope					
	KNOWLEDGE	3.57	0.40	9.03	2063	<0.001*
	WORD FORMAT*KNOWLEDGE	1.54	0.39	3.93	2063	<0.001*
	ITEM TYPE*KNOWLEDGE	0.50	0.38	1.32	2063	0.186
	WORD FORMAT*ITEM TYPE *KNOWLEDGE	−0.95	0.37	−2.53	2063	0.011*
Effect of content knowledge (Comparing Known and Fluent Items)	Intercept					
	MEAN ESTIMATE	28.24	1.81			
	WORD FORMAT	1.98	1.74	1.14	105	0.257
	ITEM TYPE	−0.85	0.64	−1.33	34	0.193
	WORD FORMAT*ITEM TYPE	0.95	0.37	2.59	1513	0.010*
	Slope					
	CONTENT	3.28	0.49	6.71	1513	<0.001*
	WORD FORMAT*CONTENT	1.07	0.47	2.26	1513	0.024
	ITEM TYPE*CONTENT	0.71	0.42	1.69	1513	0.091
	WORD FORMAT*ITEM TYPE *CONTENT	−0.71	0.41	−1.72	1513	0.085
Effect of fluency (Comparing Fluent and Unknown items)	Intercept					
	MEAN ESTIMATE	25.53	1.68			
	WORD FORMAT	1.02	1.58	0.64	105	0.521
	ITEM TYPE	−1.19	0.62	−1.93	34	0.062
	WORD FORMAT*ITEM TYPE	1.64	0.27	6.17	2691	< 0.001*
	Slope					
	FLUENCY	1.13	0.28	4.05	2691	< 0.001*
	WORD FORMAT* FLUENCY	0.54	0.28	1.96	2691	0.050
	ITEM TYPE* FLUENCY	−0.18	0.27	−0.64	2691	0.520
	WORD FORMAT*ITEM TYPE *FLUENCY	−0.32	0.28	−1.19	2691	0.234

so) and to estimate the percentage of psychology students in the study who would know the answer. Which lists participants were given in the Learning Phase and the order in which the lists were presented were randomized across participants. Within each list, the items appeared in a fixed order for all participants.

4.2. Results

For each participant, peer estimates for Known questions (eliminating any questions that participants did not remember or answered incorrectly) were averaged to provide the Known score. Similarly, peer estimates for Fluent and Unknown questions were averaged within each category to provide the Fluent and Unknown scores, eliminating any question that participants answered.

A mixed ANOVA was conducted with Knowledge (Known, Fluent or Unknown) as a within-subjects factor and List Order as a between-subjects variable. The Hyundt-Feldt correction was applied because of evidence that the sphericity assumption was violated in the within-subjects variable (note that this correction renders the F-tests more conservative). Planned pairwise comparisons subsequently tested for the effects of content knowledge and fluency, respectively, by comparing mean estimates on Known and Fluent items, and on Fluent and Unknown items. The ANOVA revealed a significant main effect of knowledge, $F(1.51, 207.81) = 120.98$, $p < 0.001$. Planned pairwise comparisons revealed a significant difference between Known (39.80%) and Fluent peer estimates (28.59%), $p < 0.001$, $d = 0.60$, as well as between Fluent and Unknown peer estimates (27.17%), $p = 0.005$, $d = 0.08$. There were no other significant main effects or interactions.

4.3. Discussion

The present experiment replicated the findings on the effects of content knowledge and fluency found in Experiments 1 and 2, with a different design that ruled out alternative explanations for the effect of fluency. Given that participants never learned the answer to the Fluent questions (and any Fluent question they knew the answer to before completing the study was removed), the difference between Fluent and New items cannot be due to any residual or implicit knowledge and therefore stem from the fluency that resulted from repeated exposure to the question. Moreover, because all items were equally likely to be included in the Known and Fluent categories, any difference between estimates could not be due to differences in the inherent difficulty of the questions.

5. General discussion

The ability to reason about what is 'common knowledge', or more importantly recognize what is *not* 'common knowledge', is a fundamental aspect of interpersonal communication and social decision-making. The primary goals of the three experiments described herein were to (a) test whether a fluency misattribution mechanism is ever sufficient to induce a curse of knowledge bias, and (b) demonstrate the impact the curse of knowledge bias and fluency misattribution processes have on people's judgments of how common knowledge is among their peers (i.e., the third manifestation of the curse of knowledge mentioned in the *Introduction*). Importantly, both content knowledge (which naturally confounds inhibition and fluency misattribution processes) and fluency in the absence of content knowledge

independently (and significantly) impacted people's judgments of the commonality of their knowledge. Across all experiments, knowledge content had a medium-sized effect on people's estimates of others' knowledge, whereas fluency had a small but reliable effect on people's peer estimates. We believe this latter effect stems from *mis*attributing the increased *subjective* sense of fluency (resulting from prior exposure(s) to the question) to an *objective* assessment of how 'widely known' the information is.

The results of all three experiments revealed that fluency misattribution is sufficient to independently contribute to the curse of knowledge bias. For instance, in Experiment 3, arguably the most stringent test of the role of fluency, participants who were more frequently asked, "Who invented the television?" judged the answer to be more widely known than those who were asked the question less frequently—even when the participants themselves did not actually know the answer. Perhaps this specific effect would more aptly be called a 'curse of familiarity'. In many naturalistic situations (i.e., outside the laboratory conditions created in these experiments), however, this effect likely works in tandem with content knowledge (and the fluency with which that content knowledge comes to mind), compounding its effects. That is, the fluency that is being misattributed in the present experiments is the result of the fluency associated with processing the question (not the answer) which is distinct from misattributions of the fluency that results when the answer comes readily and easily to mind (because here, *the information does not come to mind at all*). Thus, it is interesting to note that any *disfluency* resulting from the answer not coming to mind appears to be at least partially outweighed by the fluency associated with the question itself. In most real-world cases where the curse of knowledge bias emerges, people possess privileged information that *readily comes to mind*. As such, the small effects observed here likely *underestimate* the role fluency misattribution plays in everyday judgements of what others know.

In the three experiments presented within, a robust curse of knowledge *content* also occurred, and was greater with the passage of time (Exp. 1). Therefore, it seems likely that both the difficulty inhibiting one's knowledge content *and* the likelihood of misattributing the fluency with which it comes to mind can work in tandem, compounding their individual effects to increase the magnitude of the curse of knowledge. It should also be acknowledged that when people are reasoning about the knowledge of others there may be other contributing factors (or processes) that come into play besides inhibitory control and fluency misattribution. For example, there is a large body of work in the adult literature that refers to 'anchoring and adjustment' (e.g., Pohl & Hell, 1996; Tversky & Kahneman, 1974). The logic with anchoring and adjustment processes is that one's own point of view is the best starting point or 'anchor' for inferring others' knowledge and then one 'adjusts' according to other information that is available. A full discussion of anchoring and adjustment is beyond the scope of this paper, but it is interesting to note that a whole host of factors have been shown to influence one's degree of adjustment, including whether one is nodding or shaking one's head while making judgments of what others know (see e.g., Pohl & Hell, 1996 for a review). We suspect that one's ability to inhibit information and one's ability to correctly attribute the source of one's fluency are important parts of the adjustment process.

In conclusion, the results reported here elucidate the mechanisms underlying a pervasive bias in judgment and decision-making referred to as the curse of knowledge, or hindsight bias—a tendency to be biased by one's current knowledge when attempting to reason about a more naïve perspective. Moreover, our findings add to a growing body of evidence that people use the relative ease or speed of their information processing experience to guide many types of judgments. Future research examining individual differences in the magnitude of the curse of knowledge bias and the relation to individual differences in (a) inhibitory control, and (b) one's tendency to fall prey to source misattributions, could shed further light on the relative contribution of each mechanism. In a similar vein, de-biasing techniques targeted at making participants aware of the tendency to misattribute the source of their sense of fluency could increase the accuracy of people's memory and judgments of what others know, as well as improve perspective taking and communication.

Appendix A

Experiment 1: Test items (obscure words and facts)

Words	Facts
Volitation	What planet has the longest day?
Nescient	What does a herpetologist study?
Exhort	Who invented television?
Bloviate	Who was the first male in space?
Hebetude	The great pyramids of Egypt are located near what city?
Patronym	What was Disney's first full-length animated feature?
Bariatrics	In 1967, what type of vertebrate was the first to be cloned via nuclear transplantation?
Crapulent	What is Petrology?
Denigrate	Which city hosted the 1960 Olympics?
Barmecide	What do butterflies taste with?
Sororal	What is the greatest use of sulfuric acid?
Acclamation	Where do locusts lay their egg?
Verily	What group used the agricultural method of terracing in the Andes Mountains during the 5th century?
Diriment	What event made the Russian woman Valentina Tereshkova famous?
Repine	The Hundred Year's War was fought between what two countries?
Deride	In what country is the tallest waterfall in the world?
Macilent	What did Joseph Priesley discover in 1774?
Incarnadine	What is the longest river in Europe?

Experiment 2: Test items (obscure words and facts)

Words	Facts
Bathymetry	Who is the Roman goddess of dawn?
Apiology	What country builds the world's largest snow castle every year?
dimity	What is the most abundant substance in the earth's crust?
balanoid	Who built the first practical refrigerating machine?
lunulate	What natural substance is the fabric 'rayon' made of?
monism	Which city were the 1928 summer Olympics held in?
Novennial	Who said: "Those who cannot remember the past are condemned to repeat it"?
Acaudate	What story, later adapted into an animated film, was written by Felix Salten in 1923?
chiliarchy	What is the name of Saturn's largest moon?
oenophile	What group of Celtic languages does the Irish language belong to?

nuciferous	Which Chinese city is located at the confluence of the Yangtze and Han rivers?
withe	In which movie did Marilyn Monroe say: "Men aren't attentive to girls who wear glasses"?
yestreen	What is celebrated in Holland on April 30 every year?
hallucal	What was the duty of a knockknobbler?
Jess	Who is the patron saint of architects?
Parosmia	How many different forces have attempted to or taken the city of Constantinople?
Ecdemic	In which year was the Aztec empire conquered?
Enallage	Which car company was Sir William Lyons a founder of?

Experiment 3: Items

Obscure trivia facts: List A

What happy homemaker chirps on TV: "It's a good thing"?
What does an oologist study?
What are you afraid of if you have stenophobia?
What colorless gas is essential in the production of fertilizers and light bulbs?
How many eyes do most spiders have?
Which physicist's last words were not understood because his nurse did not speak German?
What popular soft drink contained the drug lithium--now available only by prescription--when it was introduced in 1929?
What southeastern state boasts the cities of Frog Jump, Only, and Sweet Lips?
What awards, founded in 1901, are funded with the help of the Bank of Sweden?
What is the more common name we use for the physical affliction known as furfur?
What is the hardest part of the normal human body?
What brand became the first sugar-free sugar substitute, in 1957?
What is the origin of the word "good-bye"?
What is the maximum weight permitted for a bowling ball?
What type of pills are known in the pharmacy business as "pillows"?
What patriotic song was originally titled "The Defense of Fort McHenry?"
What taste are cats unable to detect?
What was the original purpose of the leaning tower of Pisa?
What movie gave Julie Andrews the chance to portray a man?
Which nation has the longest school year?
Which explorer introduced pigs to North America?
When British film companies buy a product called Kensington Gore, what are they purchasing?
What is the minimum number of musicians a band must have to be considered a "big band"?
What early scientist, after being forced to declare the Earth was motionless, muttered: "Nevertheless, it does move"?
In Norway, a fjord is made up largely of what?
How many ribs does man have?
How many tiles are there in a game of dominoes?
What was the name of Cheerios when it was first marketed 50 years ago?

Obscure trivia facts: List B

What was a gladiator armed with, in addition to a dagger and spear?
Which explorer introduced pigs to North America?
What does an oologist study?
What is a cluster or bunch of bananas called?
What are you afraid of if you have stenophobia?
What is the maximum weight permitted for a bowling ball?
What weather phenomenon is measured by the Beaufort scale?
What was the original purpose of the leaning tower of Pisa?
How many eyes do most spiders have?
Which continent is cut into two fairly equal halves by the Tropic of Capricorn?
What early scientist, after being forced to declare the Earth was motionless, muttered: "Nevertheless, it does move"?
What is the origin of the word "good-bye"?
How many pentagonal patches are there on a soccer ball?
What vaccine caused more death and illness than the disease it was intended to prevent?

Which nation has the longest school year?
What colorless gas is essential in the production of fertilizers and light bulbs?
When British film companies buy a product called Kensington Gore, what are they purchasing?
When the bald eagle was first named, what was the meaning of the word bald?
What added ingredient keeps confectioners' sugar from clumping?
What brand became the first sugar-free sugar substitute, in 1957?
What insect depends the most upon sight, rather than sound, to locate mates?
What is the more common name we use for the physical affliction known as furfur?
What popular soft drink contained the drug lithium--now available only by prescription--when it was introduced in 1929?
Who had a thick-gummed best friend named Bubba Blue?
What was the first organ successfully transplanted from a cadaver to a live person?
What Greek math whiz noticed that the morning star and evening star were one and the same, in 530 BCE?
What is the most plentiful metal in the earth's crust?
What's a flat image that can be displayed in three dimensions?

Obscure trivia facts: List C

What colorless gas is essential in the production of fertilizers and light bulbs?
How many ribs does man have?
What type of pills are known in the pharmacy business as "pillows"?
What is the maximum weight permitted for a bowling ball?
What brand became the first sugar-free sugar substitute, in 1957?
What is the hardest part of the normal human body?
When British film companies buy a product called Kensington Gore, what are they purchasing?
What taste are cats unable to detect?
What does an oologist study?
Which nation has the longest school year?
What movie gave Julie Andrews the chance to portray a man?
What was the name of Cheerios when it was first marketed 50 years ago?
What is the minimum number of musicians a band must have to be considered a "big band"?
What happy homemaker chirps on TV: "It's a good thing"?
How many eyes do most spiders have?
What is the origin of the word "good-bye"?
What early scientist, after being forced to declare the Earth was motionless, muttered: "Nevertheless, it does move"?
How many tiles are there in a game of dominoes?
What patriotic song was originally titled "The Defense of Fort McHenry"?
Which physicist's last words were not understood because his nurse did not speak German?
What was the original purpose of the leaning tower of Pisa?
What awards, founded in 1901, are funded with the help of the Bank of Sweden?
What southeastern state boasts the cities of Frog Jump, Only, and Sweet Lips?
What is the more common name we use for the physical affliction known as furfur?
What popular soft drink contained the drug lithium--now available only by prescription--when it was introduced in 1929?
What are you afraid of if you have stenophobia?
Which explorer introduced pigs to North America?
In Norway, a fjord is made up largely of what?

Filler items (varying level of difficulty)

What year was Canada founded in?
How many American states are there?
What is the biggest planet in the solar system?
What Christian holiday takes place on the Sunday after the first spring full moon?
Where did the 2004 Olympics take place?
Who was the first communist Russian president?
What trophy is awarded each year by the NHL?
Which mammal can fly?
What temperature does ice melt at?
What popular movie starred Leonardo DiCaprio and Kate Winslet?

What is the name that denotes the short people in the Lord of the Rings saga?
What continent did humans first come from?
What country did Mao Tse Tung rule?
What is the highest mountain in the Himalayas?
What is the present-day currency of France?
What is the name of the celestial body that was until recently considered a planet of our solar system?
Who came up with the theory of relativity?
How many books are there in the Harry Potter series?
Who wrote the novel "1984"?
In which famous 1965 musical motion picture did Julie Andrews star as a governess in pre-war Austria?
In which Oscar-winning movie does Tom Hanks say: "Mama always said life was like a box a chocolates, never know what you're gonna get"?

Which French king was nicknamed the Sun King?
Which author created the character of Hercule Poirot?
Which broad food group does cauliflower belong to?

Appendix B. Supplementary material

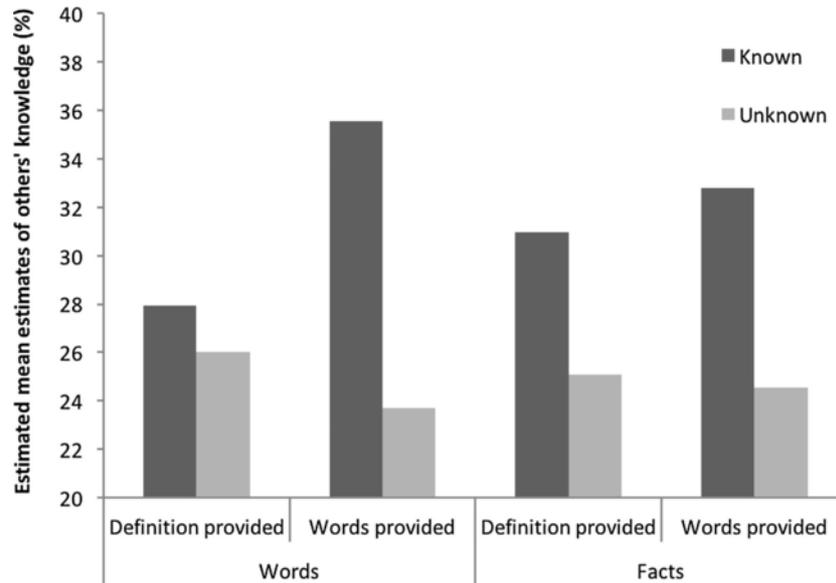Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2017.04.015.

Fig. 1. Experiment 2: Plotting the effects of Word Format Item Type and Knowledge categories.

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