The Incremental Insight Model: from individuals to networks

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1. INTRODUCTION

A well-established literature has focused on the processes involved in problem-solving (Nagel, 1996). Such focus is warranted, given the impact that this understanding could have for society, from structuring educational environments to creating the conditions to spur innovation in scientific discovery and industry applications (van Steenburgh et al. 2012). Importantly, this literature has differentiated between two types of problems: those that require analytic processing and those that require insightful resolution (Metcalfe & Wiebe, 1987). Analytic processing involves using a pre-determined plan to produce a logical pattern of thought. It relies on a model of the problem solver as a rational decision-maker. In contrast, insightful problem solving occurs when individuals prioritize intuitive judgments and do not attempt to analytically solve the problem.

1.1 The Incremental Insight Model

We focus here on problem solving that involves insightful resolution. An insight problem is a problem that requires shifting one's perspective and viewing the problem in a novel way in order to achieve the solution (Meyer, Dow & Mayer 2003). This shift in perspective is oftentimes associated with overcoming a fixation on irrelevant information and habitual processing pathways (Kounios & Beeman, 2014; Luo & Niki, 2003). Problem-solving, in this instance, requires overcoming intuition biases by considering alternative categories. The question arises: how could one overcome these intuition biases that provide automatic ways to simplify complex problems? Our proposal –formalized in the *Incremental Insight Model* - is that exposure to inferences that are bias-inconsistent could diminish the impact of these intuition biases during the problem-solving process. This model assimilates two psychologically-grounded assumptions in the problem-solving process: (1) that people's intuition biases meaningfully impact the representation of the problem and (2) external sources could alter the degree of bias that operates during reasoning.

We, thus, postulate that the probability to successfully solve insight problems depends on the cognitive accessibility of bias-inconsistent inferences in the cognitive system. The higher the accessibility of these inferences, the more likely one is to produce the insight necessary for problem-solving (Xu & Metcalfe, 2016). If this is the case, then one pathway to insightful problem-solving involves integrating bias-inconsistent inferences from external sources. One such important external source is constituted by other individuals in our social circles (Naidu & Bedgood, 2011). A burgeoning literature in both psychology and sociology has found that social influence processes could dramatically impact collective phenomena (Christakis & Fowler, 2007; 2009). In line with existing approaches, we define collective problem-solving as problem-solving performed by interdependent agents (Guazzini, Vilone, Donati, Nardi, & Levnajic, 2015). We note that our approach differs from wisdom of the crowd type investigations, which rely on independent actions of collectively aggregated individuals (Lorenz, Rauhut, Schweitzer, & Helbing, 2011). We instead focus on a particular sub-domain of collective problem-solving, which involves problem-solving performed individually by interdependent agents (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010). With this project we aim to investigate people's intuition biases in the collective problem-solving process and to alter these intuitions through network-based interventions (Valente, 2012).

1.2 Experimental framework

The main aim of this project is to establish whether insightful resolution involves an incremental process of information accumulation (Metcalfe & Wiebe, 1987) and if so, whether one could leverage social networks to facilitate collective problem solving. First, we conjecture that the more inferences participants receive that are inconsistent with their intuition biases, the more likely they are to solve the problem correctly. And second, we hypothesize that structuring social networks to include de-biased individuals in strategic positions could result in increased collective problem solving in these communities. In order to test these hypotheses, we adapted a problem that was previously found to trigger people's intuition biases and which could be amenable to an incremental integration of information: the Speeding Car Stumper (Bar-Hillel, Noah, & Frederick, 2018). As part of the story, participants read sentences that included 5 critical items. Each of the critical items can be consistent with either a day or a night cognitive frame. Previous research shows that participants tended to adopt a night frame (i.e., intuitive bias) and reached sub-optimal solutions as a consequence (Bar-Hillel, Noah, & Frederick, 2018). Alternatively, participants who activate a day frame are more likely to solve the problem correctly. Importantly, the participants' inferences as to what those 5 critical items could be can be categorized as either day-consistent or night-consistent. For instance, the sentence containing one of the critical items (i.e., *insect*) is: "An insect flutters by, catching the driver's eye with its irregular movements and large patterned wings." The story we developed does not include a particular exemplar of insect, but if participants are asked to make inferences as to what the insect could have been, such inferences can be either day-consistent (e.g., butterfly) or night-consistent (e.g., moth). In Study 1, we first tested the basic predictions of the Incremental Insight Model: that the frame participants received at encoding (Day or Night frame) impacts the likelihood of solving the problem.

Study 1: the frame at encoding affects problem-solving rates. Reading the Speeding Car Stumper with a Day frame should cause participants to produce a low proportion of night inferences for the critical items, while reading the story with a Night frame should cause participants to produce a high proportion of night inferences. We also expected that participants who received a Day frame will have a higher rate of successful resolution of the problem compared to participants in the Night frame.

Participants and procedure. Sixty-three MTurk participants (Mean-age=32.5, female=56%) were randomly assigned to one of two conditions: Night condition (N = 33) or Day condition (N = 30) and were exposed to the Speeding Car Stumper. They were compensated at a fixed rate, independent of performance. The only difference between the Day frame condition and the Night frame condition was the first sentence of the story they read. In the Day frame condition, the story started with: "It's the middle of the day, the sun is out, and the skies are heavily clouded," while the first sentence in the Night frame condition was: "The street lights are not on, the moon is not out, and the skies are heavily clouded." Next, in both conditions, participants read the Speeding Car Stumper. After a 3-minute distracter, participants made inferences for each of the critical items (e.g., *What do you think the insect that distracted the driver was?*). Finally, participants were again provided with the same story they read initially and were instructed to answer the riddle.

Coding. To understand whether the encoding frame influenced the inferences that the participants made, we had a separate sample of 69 MTurk participants (Mean-age=31.5, Female=58%) rate all the inferences produced by the initial sample on a 1-100 Likert scale. They indicated whether each specific inference was likely to be seen during the Day (i.e., 0) or during the Night (i.e., 100). Scores were averaged across these 69 participants for each of the inferences that participants in the initial study made. Inferences with average scores lower than 50 were classified as Day, those above 50 were labeled as Night.

Results. We found that the proportion of night inferences in the Night frame condition was significantly higher (M=.33; SD=.09) than the proportion of night inferences in the Day frame condition (M=.19; SD=.07), Cohen's d=1.75, $t(61) = 6.84$, $p < .001$. More importantly, participants in the Day frame condition were more likely to solve the problem correctly than participants in the Night frame condition, $\chi^2(1, N=63) = 4.46$, $p < .04$. Having established that the encoding frame not only impacts the inferences that people make but also the probability of finding the solution, we set out to investigate whether these bias-inconsistent inferences have a similar impact in a conversational context.

Study 2: reducing intuitive biases through conversational interactions. *Participants and procedure.* We recruited 120 participants at Princeton University (Mean-age=20.5, Female=63%). The participants were paired in dyads and randomly assigned to one of three experimental conditions. They received research credit for participation, independent on performance. In the Day-Day condition (N=30), both participants were exposed to the Day frame story, in the Night-Night condition (*N*=30) both participants were exposed to the Night frame story, and in the Day-Night condition (*N*=60) one participant in the pair was exposed to the Day frame story and the other participant was exposed to the Night frame story. After a brief distracter task, participants were asked to individually make inferences about the 5 critical items they were presented with as part of the story. Next, they were instructed to have a conversation with one another to discuss “the inferences each of you made with regard to the story you both read.” Finally, participants individually read the story again and attempted to solve the riddle.

Results. We found that participants in the Night frame condition produced more night inferences (M=41; SD=.09) than participants in the Day frame condition (M=.16; SD=.06). Cohen’s d=3.33, t(118)=17.90, $p < .001$. We also replicated the finding that participants in the Day-Day condition were significantly more likely to solve the problem than participants in the Night-Night condition, $\chi^2(1, N=60) = 6.67$, $p < .01$. In mixed (Day-Night) pairs, we found that participants who were given a Day frame were more likely to solve the problem correctly than participants in the Night frame, $\chi^2(1, N=60) = 5.40$, $p < .02$, as expected. Participants who were given a Night frame and were paired with participants who were given a Day frame were slightly more likely to solve the problem correctly (37%) than participants who read the Night frame story and were paired with other Night frame participants (32%). Similarly, participants who read the Day frame story who were paired with Night frame participants were more likely to solve the problem correctly (68%) than participants in the Day frame condition paired with other Day frame participants (60%). Based on these findings, we reasoned that if receiving bias-inconsistent inferences from others impacts problem-solving at a dyadic level, then the propagation of bias-inconsistent inferences through networked communities will affect collective problem-solving in predictable ways.

Study 3: collective problem-solving in social networks*. Participants and procedure*. One hundred participants were recruited on the Princeton University campus (Mean-age=20.7, Female=59%). They arrived in the lab in groups of 10 and were randomly assigned to one of two conditions: The Homogeneous First condition and the Heterogeneous First condition. The experiment took place in four phases. In Phase 1, participants read the stumper. In Phase 2, they made inferences about the five ambiguous critical items individually. In Phase 3, participants went through a sequence of chat-mediated conversational interactions and took turns in making inferences about the critical items. There were 4 rounds of conversations that effectively created a conversational network (Fig.1). Participants discussed their inferences with their conversational partner. We varied the temporal sequence of conversations in the network, such that in the Homogeneous First Condition participants first interacted with other participants who were provided with the same frame, while in the Heterogeneous First Condition, participants first interacted with participants who were assigned the opposite frame. Based on the Incremental Insight Model, we expected that the correct problem-solving rates should be higher in the Heterogeneous First Condition than in the Homogeneous First Condition

Results. Data collection is still in progress for Study 3.

Conclusion. These findings have both theoretical and applied relevance. They should be of interest to psychologists interested in exploring how the cognitive processes involved in problem-solving impact collective-level outcomes, to sociologists who want to understand how cognition interacts with structural features of social networks to shape collective problem-solving, and to behavioral economists who are interested in designing strategies to overcome people’s biases at a large scale. At the same time the advances made as part of this project could be applied to a range of practical situations, from problem-solving in crowd-based platforms to societal efforts to deal with people’s intuition biases.

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