On the Link between Cognitive Control and Heuristic Processes

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Abstract

In several experiments, we demonstrate that controlled cognition (e.g., "System 2," as measured by the cognitive reflection test) can give rise to seemingly intuitive judgments (e.g., "System 1"). Experiment 2 examined a bias that occurs when price estimates are made in the presence of unfamiliar (disfluent) money. Paradoxically, more controlled cognition was related to a greater reliance on disfluency as a basis for judgment, which led to a large devaluation bias. Experiment 3 examined how the ease of company name pronunciation (fluency) influenced company profit estimation. Paradoxically, more controlled cognition was related to a greater reliance on the ease of company name pronunciation as a basis for stock profit estimations. Effects were independent of basic working memory capacities and did not interact with age. Results highlight the often neglected relations between cognitive control and heuristic processes. Results also provide some new evidence on the potential influence of an early selection mode of cognitive control.

Keywords: judgment; decision making; aging; bias; fluency; dual process; cognitive reflection; heuristic; working memory

Dual System Theories

Drawing on various dual process theories, researchers have posited a general theoretical framework describing the interplay of two fundamental cognitive systems (Evans, 2008; Sloman, 1996; Stanovich and West, 2000). The intuitive "System 1"—sometimes referred to as "the heuristic system"—is said to involve automatic, contextualized, heuristic, affective, and associative processes, which rapidly give rise to impressions (Kahneman, 2003). In contrast, "System 2" is said to rely on effortful, decontextualized, abstract, serial processes, that either use rule-based mechanisms (such as logic) to compute responses or otherwise monitor and adjust the output of "System 1" (for a review see Evans 2008).[1] Although this general framework has met with strong criticism (e.g., arguments that the framework is internally inconsistent and too imprecise to make meaningful predictions; see Gigerenzer & Regier, 1996), the interplay of the two systems has been widely used to organize and explain findings in the judgment and decision making literature (Evans, 2008; Kahneman, 2003).

Cognitive Abilities and Decision Making Key evidence used in support of a general dual systems theory is the correlation between cognitive abilities and superior reasoning, judgment, and decision making (Stanovich & West, 2000). Theoretically, it is often assumed that the link between abilities and decision making results from the fact that more able individuals have more cognitive resources available, enabling the computation of more normative decisions via logical and normative processes ("System 2"). Indeed, "the notion that System 2 is in some sense rule-based is compatible with the proposals of most dual process theorists" (p. 261, Evans 2008). For example, Stanovich and West (2000) have noted that "high analytic intelligence may lead to task construals that track normative rationality" (p. 662) and that "normative responses are computationally more complex, and only those people with the requisite computational power are able to compute them" (p. 706). Specifically, "System 2" is said to be constrained by limited working memory resources wherein larger working memory capacities are necessary for the inhibition of inappropriate heuristics ("System 1") and/or the representation of more abstract, normative decision processes ("System 2").

Elaborative heuristic search Recent research indicates that the relationships between decision making (i.e., risky choices) and cognitive abilities (e.g., working memory, numeracy, cognitive reflection) can result from differences in heuristic-type exploration and representation of the problem space, rather than the use of more normative decision strategies. Specifically, protocol analysis revealed that normative decisions were strongly related to participants' more elaborative heuristic search processes[2] (e.g., verbalized considerations of more diverse aspects of differences in lotteries), which fully mediated the relationships between cognitive ability measures and normative choices (Cokely & Kelley, 2009). Indeed, fewer than 5% of the participants verbalized processes consistent with normative computations although most of the participants made normative choices. These results echo well established findings relating heuristic search processes to deliberative cognition in expertise. For example, superior move selection in chess results, in part, from increased rates

[1] The exact nature of the interplay of the systems is debated. Dynamics are commonly taken as default-interventionist (i.e., one process monitors and corrects the other) or parallel-competitive (i.e., both processes compute independent outputs) (Evans, 2008).

[2] In this paper, *Heuristic search* refers specifically to Herbert Simon's notion of heuristics as problem solving processes that rely on selective (i.e., non-exhaustive) problem space search.

and depths of deliberative heuristic search (Gobet & Charness, 2006). Cokely and Kelley (2009) further hypothesized that the relationship between superior performance and cognitive abilities may often result, at least in part, from more elaborative encoding (Cokely, Kelley, & Gilchrist, 2006) and more heuristic search processes (see also *reflectiveness*, Baron, 1985).

In the current experiments, we sought to provide new evidence on the relationship between the use of cognitive control (i.e., "System 2") and elaborative heuristic search processes. We hypothesized that in environments in which multiple diagnostic cues were available, more controlled processes ("System 2") would lead to more normatively justifiably judgments, as is typically found in the literature. In contrast, however, in environments in which few if any diagnostic cues were available, we hypothesized that more controlled processing ("System 2") could be paradoxically related to a greater reliance on heuristic processes (normally ascribed to "System 1"). Accordingly, we hypothesized that in some environments more cognitive control ("System 2") could be related to non-normative biases.

Experiment 1

Experiment 1 was designed to show that in environments with both diagnostic and non-diagnostic cues, controlled processes can be associated with more normatively justifiable judgments as a result of more elaborative heuristic search processes (Cokely & Kelley, 2009). Previous research has revealed that consumer judgments regarding the value of an item (e.g., an Mp3 music player) can be influenced by the balance of automatic and controlled processing. When participants were induced to use more controlled processing they were more likely to notice diagnostic information about an Mp3 player and adjust their judgments of its value accordingly (Alter & Oppenheimer, 2006). As a conceptual replication, we hypothesized that individual differences in the tendency to use controlled processing would also be associated with differences in willingness-to-pay judgments. That is, if more use of controlled processing (as measured by the cognitive reflection test, which is designed to measure differences in System 2 versus System 1 processes; see materials) predicts more elaborative heuristic search these participants should be more likely to encode the presence of diagnostic cues (e.g., high storage capacity, uncommon durability) making them more willing to pay a higher price for the high quality Mp3 player. In contrast a lower use of controlled processing should be associated with a lower likelihood to encode the presence of diagnostic cues and thus should produce a greater influence of the non-diagnostic cue on judgments leading to lower willingness-to-pay judgments.

Participants Forty-six participants (M = 24.0 years) were recruited at the Max Planck Institute for Human Development (Berlin). Participants received 10€ for their first hour of participation and 7€ for every hour thereafter.

Materials & Procedure Participants first completed the cognitive reflection test (CRT)—an instrument designed to measure differences in a participant's tendency to rely on more controlled ("System 2") versus automatic ("System 1") processing (Frederick, 2005). Participants next read a technical review of a high-quality Mp3-player that contained both diagnostic cues (e.g., large music storage capacity, high durability) and a non-diagnostic cue (i.e. a picture of an incompetent-looking person). Lastly, participants made a price estimation judgment indicating the amount of money they would be willing to pay for such an Mp3 player.[3]

Results & Discussion Median splits[4] were computed to define lower (M = .67, SD = .49) and higher (M = 2.39, SD = .50) cognitive reflection groups. An analysis of variance (ANOVA) with cognitive reflection group (lower, higher) as a between-subjects variable revealed a moderate sized significant difference in willingness-to-pay judgments, F (1, 44) = 3.9, p = .05, η_p^2 = .08. As predicted, lower reflection was associated with lower willingness-to-pay judgments (M = €72.4, SD = €56.1) as compared to higher reflection (M = €105.5, SD = €55.1). Results are consistent with data from Alter and Oppenheimer (2006) indicating that the use of more controlled processing can be related to a greater detection and use of diagnostic cues for judgment (e.g., quality of Mp3 player), while the use of more automatic processing can be related to a higher reliance on a highly salient non-diagnostic cue (i.e., a picture of an incompetent looking advisor). Results are also consistent with an elaborative heuristic search hypothesis, indicating that higher cognitive reflection can be associated with more elaborative information search and encoding processes in

[3] We used the same materials used in Alter and Oppenheimer (2006), translated into German.

[4] Because the CRT is a relatively new, very short instrument (three item test), its psychometric properties are not well understood. *A priori* we decided to use median splits for data analysis as this allowed for conservation of power without unnecessary assumptions (e.g., a critical assumption is that test scores are roughly monotonically increasing, i.e., that CRT scores are at least ordinal). In all studies, median splits in younger adults included lower (0-1 CRT scores) and higher (2-3 CRT scores) groups. Median splits in older adults included lower (0 CRT scores) and higher (1-3 CRT scores) groups. There are potential concerns using different cut off points for younger and older CRT groups; however, following our *a priori* data analysis plan circumvented issues that would arise from alternative analyses (e.g., CRT scores were differentially distributed in younger and older adults). Additional analyses indicate that in both the current lower and higher CRT groups, younger and older adults showed similar differences in working memory capacity scores (about 1.5 standard deviations). Additional exploratory analyses of Experiments 3a & 3B using a regression framework also provided evidence of the reliability of median split analyses and suggested that the monotonic assumption is valid with respect to some judgments (i.e., stock profit estimations).

consumer judgments. Further process tracing research is needed to more precisely identify search parameters. [5]

Experiment 2

Experiment 2 was designed to show that in certain environments controlled cognition ("System 2") could result in non-normative judgment biases. Specifically, previous research has revealed a surprising bias wherein money that is less familiar, but still regarded as genuine, will tend to be seen as less valuable than more familiar money. When participants were asked to judge the purchasing power (e.g., how many pencils could one buy) of some amount of money (e.g., a dollar) they tended to estimate that purchasing power was lower when the question was presented along with a picture of unfamiliar money (i.e., a one dollar coin) than when presented with a picture of familiar money (i.e., a one dollar bill) (Alter & Oppenheimer, 2008). Theoretically, this difference is the result of an unconscious inference based on one's subjective un-ease of information processing, e.g. disfluency, which leads people to dislike and devalue the unfamiliar currency. We hypothesized that this seemingly automatic judgment asymmetry could depend on the extent to which participants attended to and elaboratively encoded the presence of the disfluent currency. High cognitive reflection scores could be associated with a more detailed representation of the disfluent and fluent money and thus may be associated with a larger judgment asymmetry (bias). Moreover, we were interested in whether this effect would rely primarily on heuristic search and elaboration or if it was critically constrained by cognitive capacity. In order to test this we examined both younger and older adults (as normal cognitive aging is known to be associated with large declines in domain general working memory and reasoning capacities) predicting that elaborative heuristic search could be relatively independent of capacity (Frederick, 2005).

Participants Ninety-four participants, both younger (N = 60; M= 25.0 years, range of 19 – 31 years) and older adults (N = 34; M= 70.0 years, range of 63 – 74 years) were tested at the Max Planck Institute for Human Development (see Exp. 1 for payment details). One older participant and two younger participants were excluded because they indicated they were familiar with the rare coin. Five older participants were excluded because they indicated they were unfamiliar with the 10 Euro bill. One participant did not complete the cognitive reflection test.

Procedure & Materials Participants first completed the cognitive reflection test. Next, participants completed a paper-and-pencil questionnaire with an instruction to make estimations about "how many of each of the items listed below could be purchased with 10 Euros." Half of the participants received a questionnaire with a picture of a commonly used 10 Euro bill (in circulation since 2002), while the other half was presented with a picture of a rare 10 Euro coin. Both images were featured prominently near the top right corner of the paper, to the right of the instructions (see Alter & Oppenheimer, 2008). Below the instructions (and picture) was a list of 10 inexpensive items (e.g., gumballs, pencils, etc.) with empty boxes for the reporting of participants' estimations. Finally, on a separate sheet of paper participants were asked to rate familiarity and genuineness of the currency presented on the questionnaire.

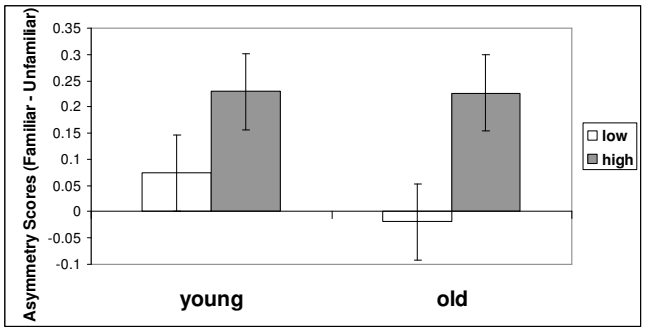

Figure 1: Y-axis represents asymmetry scores (familiar-unfamiliar), which indicate the strength of the devaluation of disfluent money. Error bars are the standard error of the mean.

Results & Discussion Median splits[4] on cognitive reflection test scores were computed for both younger (lower, M = .33, SD = .48; higher M = 2.42, SD = .50) and older adults (lower M = .00, SD = .00; higher M = 1.55, SD = .73). Next, following Alter & Oppenheimer (2008) mean item estimates (i.e., the estimated number of objects that could be purchased for each item type) were transformed into z-scores representing differences in relative purchasing power on the same scale. We next computed asymmetry scores (familiar condition-unfamiliar condition) for all item means, which served as an indicator of the strength of the effect—i.e., the extent to which familiar currency was rated as more valuable than unfamiliar currency. An ANOVA with cognitive reflection (lower, higher) and age (younger, older) as between-subjects variables and the z-scored asymmetries as dependent variable revealed a main effect of cognitive reflection, F (1, 36) = 5.95, p = .02, η_p^2 = .14. Age did not interact with cognitive reflection (F < 1). Lower cognitive reflection was associated with little-to-no asymmetry (younger M = .07, SD = .34; older M = -.02, SD = .24) while higher reflection was associated with a large asymmetry (younger M = .23, SD = .19; older M = .23, SD = .25) (Figure 1). Results indicate that (1) the use of more controlled processes was paradoxically associated with the use of the heuristic for judgment (and thus a bias in this environment) and (2) that the size of the asymmetry was largely independent of working memory capacity (primarily reflecting encoding processes).

Experiment 3

Experiment 3 was designed to show that in certain environments more reliance on seemingly automatic and

[5] See Alter & Oppenheimer (2006) for causal evidence that higher cognitive reflection primarily involves increasing use of diagnostic information.

intuitive judgment processes (i.e., one's use of fluency as a cue for judgment) can reflect controlled cognition. Judgments are known to be influenced, sometimes dramatically, by cognitive fluency. For instance, the relative ease of company name pronunciation (fluency) influences participants' estimates of a company's stock profitability (Alter & Oppenheimer, 2006). This effect has been observed for past profit estimates of fictional companies and has also been seen in the trading behavior of US companies during initial public offerings. Theoretically, influences of fluency on judgment in these types of financial decisions are assumed to reflect (1) an attempt to make sense out of very complicated material with only non-diagnostic information being available and (2) an unconscious inference whereby more fluently processed information is perceived as both more familiar and more affectively pleasant (Alter & Oppenheimer, 2006).

We hypothesized that in the current environment the degree to which one relies on fluency would depend critically on one's use of controlled processing. While dual systems theory predicts that higher reflection should be associated with equal or less reliance on fluency for judgment, we hypothesized that in the absence of other diagnostic cues more controlled processing ("System 2") of the available cue should lead to a more detailed representation of that cue (as in Experiment 2), and thus more reliance on fluency as a heuristic cue.[6] Hence, higher reflection could promote a finer-grained sense of the ease of name pronunciation which could then be reflected in judgment. As in Experiment 2, we hypothesized that influences of cognitive reflection (i.e., elaborative search processes) were likely to be independent of domain general cognitive capacity. Therefore, higher reflection participants were expected to show more reliance on fluency regardless of their age. For ease of explication the experiment is presented in two parts (note: the same younger participant control group is used for both experiments):[7] Experiment 3a examined the use of fluency with cognitive reflection and aging; Experiment 3b directly manipulated cognitive reflection in younger adults.

Experiment 3a

Participants Eighty participants, both younger (N = 46, M= 24.0 years, range of 20 - 35 years) and older adults (N = 34, M= 70.0 years, range of 63 – 74 years) were recruited at the Max Planck Institute for Human Development (Berlin) and were paid for participation (see Exp. 1). Ten participants were excluded: Seven older participants did not complete the stock profit estimation task; two participants responded null to every item; one participant did not complete the cognitive reflection task.

Materials & Procedure Participants first completed the cognitive reflection test. Participants were then presented with a list of 30 fictitious German company names[8] and were instructed to estimate the changes in stock value over the last 12 months (estimated percent change). The only cue for judgment that was provided was the company name, which systematically varied in its ease of pronunciation (e.g. Flinks v. Ägädux).

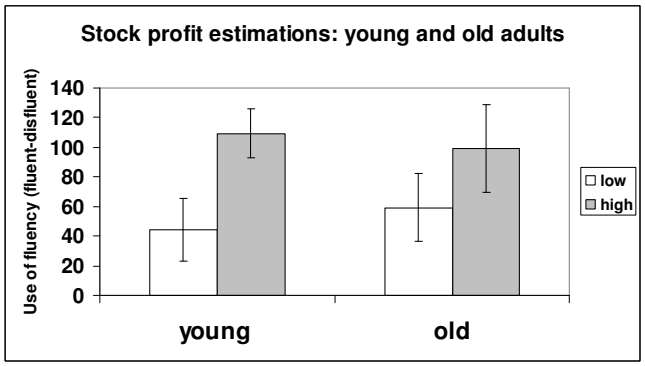

Figure 2: Y-axis represents the total use of fluency (fluent-disfluent). Error bars are the standard error of the mean.

Results & Discussion Ten independent raters—all of whom were native German speakers—were asked to rate the ease of pronunciation of each of the 30 fictitious German company names on a 3 point scale from easy to difficult. The easiest eight names to pronounce (top quartile) were operationalized as fluent names while the hardest eight names to pronounce (bottom quartile) were operationalized as disfluent names. A total fluency use score was computed as the difference in profit estimations for the fluent company names minus the disfluent company names. Median splits[4] were performed on cognitive reflection scores for both younger (lower M = .67, SD = .49; higher M = 2.4, SD = .50) and older adults (lower M = .00, SD = .00; higher M = 1.55, SD = .73).

An ANOVA with cognitive reflection (lower, higher) and age (younger, older) as between-subjects variables revealed a moderate sized significant effect of cognitive reflection on fluency use, F (1, 66) = 5.2, p = .03, η_p^2 = .07. Age did not interact with cognitive reflection (F < 1) (Figure 2). Independent of age, lower cognitive reflection scores were associated with less fluency use (younger M = 44.44, SD = 82.05; older M = 59.33, SD = 90.23) while higher reflection scores were associated with more reliance on fluency (younger M = 109.29, SD = 94.60; older M = 98.89, SD = 78.2). In a task environment in which fluency was the only available cue (i.e., the only available cue designed to systematically vary) higher cognitive reflection (System 2) was paradoxically associated with more reliance on the use

[6] This hypothesis was developed following the analysis of the younger control condition data but before the analysis of the data from either (1) the older adults or (2) younger adults in the brow-furrowing condition.

[7] A combined analysis including all data (Exp 3a & 3b), using both median splits or a regression framework, was consistent with the presented results and theoretical interpretations.

[8] The company names were German-style transformations of the company names used in Alter and Oppenheimer (2006).

of the heuristic cue (i.e., fluency) as a basis for judgment. This pattern was independent of age, suggesting that results primarily reflect elaborative heuristic search (rather than capacity).

Experiment 3b

In Experiment 3b we sought to causally increase controlled processing thereby increasing participants' reliance on fluency as a basis for judgment. We manipulated controlled processing by instructing half of the participants to furrow their brows while completing the stock profit estimation task. This facial expression is consistent with the exercise of cognitive effort and has been shown to induce more reflective processing (Alter & Oppenheimer et al., 2007).

Participants Ninety-two younger adults (*M*= 24.3 years, range of 18 - 35 years) participated in the study at the Max Planck Institute for Human Development (Berlin) and were paid for participation (see Exp. 1).

Materials & Procedure Materials and procedure were the same as in Exp. 3a except that half of the participants were instructed to furrow their brows during estimation.

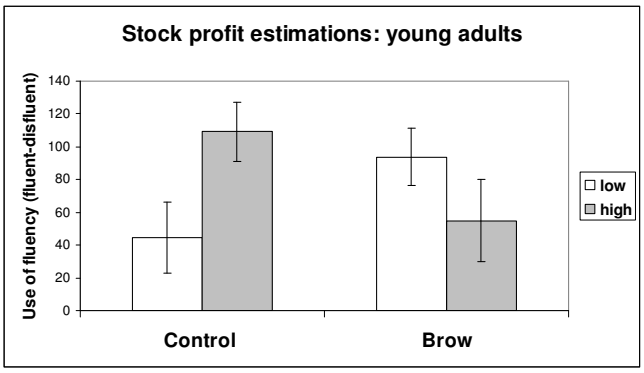

Figure 3: Y-axis represents the total use of fluency (fluent-disfluent). Error bars represent the standard error of the mean.

Results & Discussion A median split was performed on cognitive reflection scores (lower *M* =.58, *SD* = .50; higher *M* = 2.38, *SD* = .50). Fluent names and total reliance on fluency were computed as in Experiment 3a. An ANOVA with the total use of fluency (fluent-disfluent) as dependent variable and cognitive reflection (lower, higher) and condition (control, brow-furrowing) as between-factors revealed a significant interaction between cognitive reflection and condition, F (1, 86) = 7.64, p =.007, η_p^2 = .08 (see figure 3).[9] In the control condition there was a clear difference between the lower reflection group's use of fluency (*M* = 44.44, *SD* = 82.05) as compared to the higher reflection group's use of fluency (*M* = 109.29, *SD* = 94.59). In the brow-furrowing condition there was a reversal of this pattern such that lower reflection was associated with more use of fluency (*M* = 93.69, *SD* = 95.55) whereas higher reflection was associated with less reliance on fluency (*M* = 55.00, *SD* = 89.25). An ANOVA next examined the change in use of fluency for lower reflection individuals revealing a significant increase in use of fluency, F (1, 46) = 4.76, p = .03, η_p^2 = .09. These results suggest that the furrowing of one's brow caused lower reflection individuals to increase their reliance on fluency, consistent with a capacity independence hypothesis. Although unexpected, the higher reflective group showed a non-significant trend toward lower reliance on fluency in the brow furrowing group, F (1, 38) = 2.65, p = .11, η_p^2 = .06. We speculate that this may reflect the influence of even more extensive and idiosyncratic heuristic search processes by higher reflection individuals (e.g., "the name sounds good but actually this sounds a bit like a financial company which is not good").

[9] Analyses also controlled for working memory span (operation span) and numeracy scores, which were included as covariates. Unreported analyses indicated that neither operation span nor numeracy significantly influenced condition or fluency use.

General Discussion

In three experiments we demonstrate that seemingly intuitive judgments sometimes reflect controlled processing. In an environment with multiple diagnostic cues, controlled processing tended to be associated with more normatively justifiable judgments. In an environment in which few if any diagnostic cues were available, controlled processing was related to a judgment bias. Although conventionally paradoxical, results remind us that mechanisms of controlled cognition—which are often assumed to involve more normative, rule based processes ("System 2")—can also rely on heuristic search processes (often associated with "System 1").

Modes of Cognitive Control The common dual systems characterization of the interplay between automatic and controlled decision making processes emphasizes *late correction* cognitive control. When controlled processes ("System 2") do not compute an answer they are assumed to primarily operate by monitoring and then adjusting or correcting the output of automatic processes (Kahneman, 2003). However, cognitive control can also use *early selection* mechanisms wherein cognitive control ("System 2") is used to generate goals, strategies, and mental contexts that can qualitatively alter the output of automatic processes ("System 1") (see Cokely & Kelley, 2009). As seen in the current experiment, by changing the way one thinks about a problem (i.e., by encoding more detailed representations or searching for more information before making a judgment), one can change intuitions.

Cognitive Abilities and Early Selection We hypothesize that the tendency to more elaboratively search and represent task environments may result from transfer of metacognitive skills that are valuable in memory, strategy adaptivity, and skill acquisition. Of note, strategic processes can cause large differences in basic cognitive capacities, such as the capacity to monitor and control interference in memory (Cokely, Kelley, & Gilchrist, 2006). By elaboratively encoding task contents before making judgments, high

reflection individuals may be more likely to develop more nuanced task representations in long-term memory. Greater encoding into long-term memory should then free attentional resources, which—together with a more precise representation—should allow better cognitive monitoring. Such a mechanism might account for the finding that high ability individuals often fail to show normative judgment on initial choices (i.e., between-subjects), although normative choices emerge upon additional trials (i.e., within-subjects) (Stanovich & West, 2008).

Implications for the cognitive reflection test The relationship between cognitive reflection and judgment was largely independent of age.[4] On average older adults had lower working memory capacity scores, F (1, 114) = 22.45, p = .001, η_p^2 = .17, yet had similar judgments in Experiments 2 and 3. This provides new evidence of discriminant validity for the cognitive reflection test, which seems to uniquely predict cognitive processes (e.g., elaborative heuristic search) and thus is not only a measure of skill or capacity (Frederick, 2005). Process-level data from a separate unreported study of older adults also supports the assumption that the cognitive reflection test can measure differences in search processes: Higher cognitive reflection scores were predicted by the total time spent on the cognitive reflection test controlling for one's general task pace (operationalized as the total time spent completing an unrelated simple demographics task), F (2, 55) = 5.26, p = .03, R^2_{change} = .09.

Conclusions

Herbert Simon defined heuristics as problem solving processes that involve selective search (Simon, 1990). Because most real-world problems are computationally intractable—as optimal solutions cannot necessarily be computed by our minds or machines—heuristic processes can be essential problem solving tools for both ill-defined (e.g., stock selection) and well-defined problems (e.g., chess). Accordingly, we often must rely on, and may benefit from, problem solving heuristics that range from easy to effortful—a fact that is largely neglected in discussions of the general dual systems framework.[10]

In the current experiments, we sought to provide vivid examples of how even seemingly intuitive judgments can sometimes reflect cognitive control. Results further document the link between cognitive control ("System 2") and heuristic use, providing more converging evidence that there is no "the" heuristic system (an admittedly disfluent phrase that we expect might trigger some of the types of elaborative encoding processes that can characterize controlled cognition). Experiments also provide new evidence extending the elaborative heuristic search hypothesis and reveal the presence of an early selection mode of cognitive control in judgment. Finally, given that judgment involves the complex interplay of persons, processes, and task environments, the current experiments serve as an illustration of the role that individual differences can play in testing and refining theory.

[10] See Evans' (2008; Kahneman & Frederick, 2002) for some discussion of the roles of heuristic-type processes in "System 2".

Acknowledgements

We thank Adam Alter and Danny Oppenheimer for feedback and materials, and Gregor Caregnato and the ABC research group for data collection and research support.

References

Alter, A. L., & Oppenheimer, D. M. (2008). Easy on the mind, easy on the wallet: Effects of fluency on valuation judgments. *Psychonomic Bulletin and Review, 15,* 985-990

Alter, A. L., Oppenheimer, D. M., Epley, N, & Eyre, R. N. (2007). Overcoming intuition: Metacognitive difficulty activates analytic reasoning. *Journal of Experimental Psychology: General,136,* 569-576.

Alter, A. L., & Oppenheimer, D. M. (2006). Predicting short-term stock fluctuations by using processing fluency. *Proceedings of the National Academy of Sciences, 103,* 9369-9372.

Cokely, E.T., & Kelley, C.M. (2009). Cognitive abilities and superior decision making under risk: A protocol analysis and process model evaluation. *Judgment and Decision Making, 4,* 20-33.

Cokely, E.T., Kelley, C.M., & Gilchrist, A.H. (2006). Sources of individual differences in working memory: Contributions of strategy to capacity. *Psychonomic Bulletin & Review, 13,* 991-997.

Evans, J. (2008). Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology, 59,* 255-278.

Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives, 19,* 24-42.

Gigerenzer, G., & Regier, T. (1996). How do we tell an association from a rule? Comment on Sloman (1996). *Psychological Bulletin, 119,* 23-26.

Gobet F. & Charness, N. (2006) *Expertise in chess.* In K. A. Ericsson, N. Charness, P. Feltovich, and R. R. Hoffman, R. R. (Eds.). Cambridge handbook of expertise and expert performance (pp. 523-538). Cambridge, UK: Cambridge University Press.

Kahneman, D. (2003). A perspective on judgment and choice - Mapping bounded rationality. *American Psychologist, 9,* 697-720.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin*, *119*, 3–22.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate. *Behavioral and Brain Sciences, 23,* 645–665.

Stanovich, K. E., & West, R. F. (2008). On the relative independence of thinking biases and cognitive ability. *Journal of Personality and Social Psychology, 94,* 672-695.