RUNNING HEAD: Intuition and Analysis in Complex Problem Solving

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Intuition versus Analysis: Strategy and Experience in Complex Everyday Problem Solving

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Abstract

Research on dual processes in cognition has found that explicit, analytical thought is more powerful and less vulnerable to heuristics and biases than is implicit, intuitive thought. However, several studies have found that holistic, intuitive processes can outperform analysis, documenting the disruptive effects of hypothesis testing, think-aloud protocols, and analytical judgments. To examine the effects of intuitive versus analytical strategy and level of experience on problem solving, first- through fourth-year undergraduates solved problems dealing with college life. Results of two studies showed that the appropriateness of strategy depends on the problem solver's level of experience. Analysis was found to be an appropriate strategy for more-experienced individuals, whereas novices scored best when they took a holistic, intuitive perspective. Similar effects of strategy were found when manipulating strategy instruction and when comparing participants based on strategy preference. Implications for research on problem solving, expertise, and dual process models are discussed.

When it comes to solving an everyday, practical problem, should the problem be approached analytically or intuitively? When leading a work team toward achieving a project deadline or making a decision about where to attend college, will analysis or intuition lead to a better solution? Should we focus on the pro's and con's of two alternatives, identify the relevant information, and solve the problem logically, or is it better to rely on an intuitive approach in which we trust our feelings and hunches about the situation? Much psychological research on problem solving has attempted to explain how individuals use logic and analysis to solve well-defined problems. However, many everyday, practical problems involve high stakes and are highly complex and ill-structured, lending themselves to a more intuitive approach. Practical problems also involve the application of intuitive, tacit knowledge, which has been gained through experience rather than explicit instruction (Sternberg et al., 2000). For practical problems, should we attempt analysis, or instead rely on intuition? I argue that the answer to this question depends on an individual's level of experience in the domain and his or her preference for thinking intuitively or analytically.

Dual Process Models

Recently, psychology has undergone a resurgence of interest in models of cognition highlighting dual processes (e.g., Epstein, 1991; Hogarth, 2001; Sloman, 1996). For example, Epstein's (1991) model describes the implicit/intuitive/experiential mode as holistic, automatic, effortless, affective, slower and more resistant to change, context-specific, and passive and preconscious, whereas the explicit/analytical/rational mode is intentional, effortful, logical, more rapidly and easily changed, context-general, and active and conscious. Dual processes have been described with respect to learning (Reber, 1989), memory (Roediger, 1990; Tulving & Schacter, 1990), and higher cognition, including judgment and decision making (Hogarth, 2001) and reasoning (Sloman, 1996). The current paper contrasts dual processes in higher cognition, extending existing research into the domain of problem solving.

Traditionally, the problem-solving literature has focused on how individuals solve well-defined problems using analytical processes such as means-end analysis and hypothesis testing, which rely on explicit metacognitive processes. Various studies of dual processes in higher cognition have emphasized the benefit of the analytical processing mode in overcoming the heuristic responses of the intuitive processing mode (e.g., Epstein, Pacini, Denes-Raj, & Heier, 1996; Greenwald & Banaji, 1995). Intuitive processing has been often noted as causing errors in judgment while rationality has been held up as an ideal. Intuition has been generally thought of by cognitive psychologists in the decision-making tradition as synonymous with heuristic (e.g., Chase, Hertwig, & Gigerenzer, 1998; Tversky & Kahneman, 1974).

However, intuition may not always lead to biased cognition but instead may be a powerful tool for thought. Theoretical work on the construct can help to clarify why researchers disagree about the value of intuition. Hill (1987-1988) describes two distinct definitions of intuition. Classical intuitionism sees intuition as a holistic processing mode, whereas inferential intuitionism defines intuition as "a heuristic that represents a logical (inferential) process in which several intermediary steps have been omitted or obscured" (p. 138). This paper adopts a classical understanding of intuition. Intuitive thinking is a holistic perspective that takes into account all types of information that often cannot be easily articulated explicitly. Intuition as a holistic process integrates all information without the potentially biasing influence of prior expectations. Holistic intuition is distinct from inferential intuition, which has its roots in an analytical process that has become automatized. Theoretically, analysis and inferential intuition are on a continuum based on automatization, but holistic intuition is thought to be a qualitatively different process altogether.

There is quite a bit of evidence from various literatures in psychology that supports the proposal that classical, holistic intuitive processes outperform analytical processes, for example in studies of nonverbal communication (Ambady & Rosenthal, 1992), judgment (Wilson & Schooler, 1991), decision making (Abernathy & Hamm, 1995; Dijksterhuis, 2004), and problem solving (Berry & Broadbent, 1988; Schooler & Melcher, 1995). Such studies have shown that analytical approaches lead to misleading hypothesis testing or the neglect of relevant information, whereas intuitive approaches allow for a holistic perspective that takes into account all information, regardless of prior hypotheses or schemas.

Dual Processes and Complexity

Hogarth (2005) has contrasted deliberate (analytical) and tacit (intuitive) processes primarily with regard to judgment and decision making phenomena. Specifically, he has argued that decisions made based on highly complex inputs will benefit from tacit processing, and those made based on less complex inputs will benefit from deliberate processing. Key to Hogarth's understanding of the value of intuition is the degree of bias in the environment in which relevant past experience was acquired. If previous experiences involved clear and immediate feedback regarding decision accuracy, the environment is considered "kind." Kind environments are conducive to the learning of accurate causal relationships and thus facilitate future decision making. In contrast, "wicked" environments are those in which feedback is unclear and/or not available in a timely manner. Such learning environments are highly biased, leading the tacit, intuitive system to yield inaccurate decisions in that domain. According to Hogarth, deliberate processing is best when bias is high and complexity is low. Conversely, tacit processing is best when bias is low and complexity is high.

Dijksterhuis and Nordgren (2006) make similar predictions about the interactive relationship between processing mode and complexity in their theory of unconscious thought. Empirical work has shown that unconscious thought (i.e., thought during a period of distraction or incubation) is superior to conscious thought (i.e., careful analysis of the problem) when the task requires the holistic processing of highly complex stimuli (Dijksterhuis, 2004). This effect was observed most strongly for complex decisions that required the integration of a great deal of information as opposed to those which required only few pieces of information for a decision to be made. This is due to the "weighting principle," the finding that the unconscious is better at calculating weights for numerous factors than is the conscious system, which tends to become biased toward information that is more easily articulated or recently activated.

Dual Processes and Experience

The fact that processing mode interacts with complexity implies that it will also interact with experience. Complexity and expertise are inversely related – the more experience an individual has, the less complex and more decomposable a problem will appear to that individual. The current work focuses on the role of dual processes and experience in practical problem solving.

Experience affects the organization of knowledge. Expert knowledge is organized according to highly sophisticated schemas, whereas novices lack this deep structure, organizing their knowledge on more surface features (Chi, Feltovich, & Glaser, 1981). These schemas enable experts to quickly highlight relevant information in a problem and process it quickly and accurately. Schemas facilitate experts' ability to analyze and interpret information in a problem, whereas novices' lack of schemas forces them to rely on other strategies for problem solving (Chi, Glaser, & Farr, 1988).

In everyday, practical problem solving, relevant knowledge is likely to be acquired through informal experience rather than direct instruction. Such knowledge is not easily articulated, and is referred to as tacit knowledge (Cianciolo, Matthew, Sternberg, & Wagner, 2006; Polanyi, 1966; Sternberg et al., 2000). Many researchers have described expert knowledge as intuitive in nature (Hogarth, 2001; Klein, 1998). Schön (1983) has explained that experienced leaders form intuitive, implicit, latent representations that reflect patterns of events in the environment acquired through experience. Problems are solved by responding spontaneously and intuitively to a situation by matching it to a similar pattern representation in memory. Experts may engage in this process very successfully, though entirely tacitly.

Sternberg and colleagues (2000) have developed measures of tacit knowledge that can reveal the presence of expertise even when this knowledge is not easily articulated. Previous research using these tacit knowledge inventories has shown that individuals with more experience have more tacit knowledge and are more likely to be able to articulate that knowledge. For example, Antonakis, Hedlund, Pretz, and Sternberg (2002) proposed a model of tacit-knowledge acquisition and application that highlighted the importance of metacognitive skills in the use of tacit knowledge. The study found that military officers at higher ranks were distinguished from those at lower ranks by their ability to articulate more detailed metacognitive knowledge in an open-ended measure of tacit knowledge. For example, given a complex scenario, the experts were better able to explicitly identify the main problem in the scenario, sift out relevant from irrelevant information, and identify consequences of possible courses of action. This result suggests that an explicit approach that emphasizes the use of metacognition may enhance practical problem solving among individuals with more experience.

Based on the literature reviewed, problem-solving performance should depend on an interaction of strategy and level of experience. Neither an analytical nor an intuitive strategy will be particularly “better” than the other for solving problems. Both Dijksterhuis and Hogarth have suggested that processing mode will interact with problem complexity, and complexity and experience can be viewed as inversely related. In fact, Hogarth (2005) has suggested that his proposed interaction of processing mode and complexity should also be examined as an interaction of processing mode and experience. These theories predict that novices will perform best when relying on the tacit system to solve problems. The performance of experienced individuals, on the other hand, will be enhanced to the extent that they use the deliberate system and rely on schemas acquired based on past experience.

The Current Work

These hypotheses were tested in two studies of college students who solved ill-defined and complex practical problems related to everyday college life. Such problems are often hard to identify and represent clearly, and hardly ever have a clear path to solution. These problems do not lend themselves to decomposition and analysis because the structure of the problem is unclear. It is the process of solving these ill-defined problems in which holistic, implicit cognition is likely to play a role, where an intuitive approach may be more effective than a logical approach (Pretz, 2001).

In order to contrast intuitive and analytical strategies in problem solving, strategy instructions were manipulated. Specifically, participants were taught to rely on either holistic intuition or analysis. Holistic intuition was induced by instructing participants to bring to mind all relevant information and trust hunches and "tacit" knowledge that may be difficult to explain or rationally justify. In this condition, participants were also encouraged to incubate by skipping items that were difficult, distracting themselves with other items, similar to Dijksterhuis's unconscious thought manipulation. Analysis was induced by instructing participants to define the problem, identify relevant from irrelevant information, and monitor problem solving carefully. This metacognitive strategy was based on the metacomponents of the componential subtheory of Sternberg's (1988) triarchic theory of intelligence.

Another way to compare the relative success of either processing mode is to compare individuals with differences in preference to engage in either mode. I will refer to individual differences in the preference to think intuitively or analytically as cognitive style. Past research has found that problem solving performance depends on an interaction of experience level and cognitive style. For example, Martinsen's (1995) study of insight problem solving showed that participants who preferred to seek novel ways of solving problem (explorers) were most successful with less experience, but that those who preferred traditional problem-solving methods (assimilators) were most successful with more experience. Using both experimental and correlational techniques allows for the discovery of converging evidence in a single design, a research strategy advocated by Cronbach (1957).

Two specific hypotheses are proposed: 1) Problem-solving success depends on an interaction of instructed strategy and experience, and 2) problem-solving success depends on an interaction of cognitive style and experience. Analytical problem solving is expected to be best for participants with sufficient experience in the problem-solving domain to perceive the logic and structure of the problem. Intuitive problem solving is expected to be best for participants with too little experience in the domain to perceive the problems as concrete and well-defined. These patterns should be observed whether the strategy is instructed or measured as a cognitive style preference.

STUDY 1

Method

Design

The study employed an analysis of covariance design. Between-subjects independent variables were manipulated strategy instruction and level of experience. The dependent variable was practical problem solving performance. Included as covariates in the design were baseline practical problem solving ability, cognitive ability, and cognitive style. Participants were assigned to a condition based on the type of strategy instruction they received. One group of participants was taught to use an intuitive approach to problem solving, a second group, an analytical approach. A control group received no instructions regarding strategy use.

Participants

Participants were 185 Yale undergraduates (118 women, 66 men; Mean age=19.47, SD=1.10; 95 first-year students and 90 juniors). All students participated during the spring semester of the academic year. Students received either credit or cash in return for their participation.

Materials

Practical problems. The problems were taken from the College Student Tacit Knowledge Inventory (CSTKI; PACE Center, 2002), a 15-item measure of tacit knowledge in the domain of college life. Brief problem scenarios are followed by a series of possible response strategies (usually approximately eight) which the participant rates in terms of their relative effectiveness on a scale ranging from 1 (extremely bad) to 7 (extremely good). (For a sample item, please see Appendix.) For more details about the development of these inventories, see Sternberg et al. (2000). In this study, two items from the CSTKI were used as practice items and as illustrations for the strategy instructions. The remaining 13 CSTKI items were used as test items.

Tacit knowledge inventories are scored using a variety of methods that generally compare individual response profiles to an expert or consensus response profile. Researchers have found that non-expert consensus response profiles and expert response profiles on tacit knowledge inventories are highly correlated (Legree, 1995; Psotka, 2003). Consensus profiles of first-year students and juniors in the present study were also highly correlated ($r = .99$), replicating these previous findings. Problem solving scores in this study were derived by calculating a standardized Euclidean distance (Mahalanobis D^2) of an individual's response profile from the sample consensus response profile. High values on problem solving reflect greater discrepancy from the consensus. The calculation of Mahalanobis distance takes into account the variance and covariance among the ratings in the comparison group. For example, this means that when there is high variability associated with the consensus response for a given response strategy, the distance of an individual rating is weighted less than when variability is low (see Rencher, 1995 for more detail).

Strategy Use Inventory (SUI). Participants completed the SUI to check actual strategy use in problem solving (see items in Table 2). Responses on the analytical and intuitive items of the SUI were averaged to obtain a measure of each participant's analytical (α = .81) and intuitive (α = .58) problem solving strategies.

Analytical and intuitive cognitive styles. To control for individual preferences for strategy use, intuitiveness and analytical thinking as individual-difference, cognitive-style variables were measured using the Rational-Experiential Inventory (REI; Epstein, Pacini, Denes-Raj & Haier, 1996; Pacini & Epstein, 1999) and the Myers-Briggs Type Indicator (MBTI; Myers, et al., 1998). The REI is a 20-item questionnaire consisting of two 10-item subscales – the rational and experiential inventories. The rational inventory (α = .78) measures an individual's preference to rely on logic and analysis in making decisions and solving problems. In contrast, the experiential inventory (α = .79) estimates the degree to which an individual prefers to rely on intuition or hunches when making decisions. The two scales have also been shown to be independent; a person may be high or low on one or both scales.

The MBTI measures individual differences in personality after Jung's (1926) theory of psychological types. The two subscales of the MBTI administered for this study were the intuitive/sensate ($\alpha = .90$) and thinking/feeling ($\alpha = .89$) scales. “Intuitive” individuals prefer imagination and abstraction, in contrast to “sensing” individuals, who prefer concrete facts. A “thinking” type of person is analytical, logical, and intellectual, whereas “feeling” types value emotion and feelings over analysis.

General cognitive ability. Because the practical problem solving measure used in this study has been found to have weak correlations with measures of *g* (Cianciolo et al., 2006), participants completed standard measures of fluid (Cattell Culture Fair Test of *g*, Scale 3, Form A; Cattell & Cattell, 1961; $\alpha = .64$) and crystallized intelligence (Mill Hill Vocabulary Test, Senior Form B; Raven, Raven, & Court, 1985; $\alpha = .69$).

Experience. Level of experience was defined as class year in Yale College. First-year participants had had 1 full semester of college experience, whereas juniors had had at least 5 semesters of college experience. First-year students were also significantly younger ($M = 18.53$ years, $SD = .54$) than juniors ($M = 20.44$ years, $SD = .59$), $t(174) = 22.39$, $p < .001$.

Procedure

Testing sessions lasting 90 to 120 minutes took place in a Yale classroom in groups of 1 to 20 participants. Each group was randomly assigned to an experimental condition. The procedure was identical for participants in all conditions, except that control group participants did not receive strategy instructions. Participants first completed the Cattell test at the direction of the experimenter, and then completed the Mill Hill test and the cognitive style questionnaires. Then participants completed two practice problem-solving items and filled out the first Strategy Use Inventory. The score on these practice items served as the baseline for each student's problem solving performance. Participants in the experimental conditions were then given the intervention instructions and asked to complete the test problems using the instructed strategy. All participants completed the SUI after completing half of the problems and again at the end of the problem set. Responses on these two inventories were combined to create a composite SUI score. Participants were then debriefed either as a group or individually.

Analytical strategy instructions. The experimenter gave participants in the analytical condition explicit instructions on how to use logic and analysis in approaching these practical problems using four steps: 1. Define the problem, 2. Identify the relevant pieces of information in the problem, 3. Decide how you will use your resources to solve the problem, and 4. Identify and evaluate the possible consequences of the potential solutions. After describing these four steps, the experimenter illustrated how the strategy could be implemented in solving each of the two practice problems the participants had just attempted. Participants were instructed to read the scenario and solve the problem using the instructed strategy while rating the quality of the response options given. While solving the test problems, participants were given a reference handout listing the four steps.

Intuitive strategy instructions. Participants in the intuitive condition were given a set of strategies that encourage the use of intuition in problem solving. The experimenter defined holistic intuition and encouraged participants to use the following problem-solving strategies: 1. Imagine the situation vividly, 2. View the problem holistically, 3. Trust your hunches and feelings about the problem, and 4. Incubate – skip the problem and come back to it later if you get stuck. After presenting these strategies, the experimenter described how they would be used in solving each of the two practice problems. Participants were instructed to read the scenario and solve the problem using the instructed strategy while rating the quality of the response options given. Participants also received a handout with the four strategies for their reference.

Control condition. Participants in the control group did not receive any instruction. They were told to solve the problems using whatever strategy felt natural to them.

Results

Before conducting the primary analyses, the data were checked for outliers, selection of cognitive style measures, success of the manipulation, and group differences on control variables. Data from six participants whose problem-solving scores were at least three standard deviations from the mean were removed from the data set. This resulted in a sample with 114 women and 64 men, 90 first-year students and 88 juniors, and 62 participants in the analytical condition, 57 in the intuitive condition, and 59 in the control group. The zero-order correlations among cognitive style variables are reported in Table 1. Because the REI experiential and MBTI thinking scales correlated with reported strategy use on the SUI, they were selected as the most valid measures of intuitive and analytical cognitive style, respectively.

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insert Table 1 about here

Based on responses to the Strategy Use Inventory (see Table 2), the manipulation check was found to be successful. Overall, participants reported using the strategy that they were instructed to use. Previous studies that have used an experimental manipulation of strategy use have found that some participants fail to comply with instructions (Sternberg & Weil, 1980), obscuring the effect of the manipulation. To clarify the effect of the manipulation on problem solving, participants were classified as either “Users” or “Non-users” based on their composite score on the SUI for the strategy in which they were instructed. Users are those participants who reported using the instructed strategy above the mean level. There were 97 participants (52 in the analytical condition, 45 in the intuitive condition) who met this criterion for having used the instructed strategy, and 23 who did not (10 in the analytical condition, 13 in the intuitive condition). All further analyses were conducted on experimental participants classified as Users and all participants in the control group.

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insert Table 2 about here

Univariate analyses of variance were conducted on each covariate as a dependent measure to examine any pre-existing differences among the participants in the experimental groups. The analyses revealed no main effects or interactions of strategy instruction and level of experience for fluid intelligence, analytical cognitive style, or intuitive cognitive style. There was a main effect of strategy instruction group on crystallized intelligence, $F(2, 150) = 4.41$, $p = .01$. Participants assigned to the intuitive strategy condition scored significantly higher on crystallized intelligence than participants in the analytical strategy condition and participants in the control group. Correlations among the covariates and problem solving scores are presented in Table 1A of the appendix. The only covariates that correlated directly with problem solving were fluid intelligence and analytical cognitive style. Higher ability scores were weakly associated with better problem solving performance, a finding consistent with prior research with these measures (Cianciolo et al., 2006). There was a weak relationship between scores on analytical cognitive style and problem solving success – participants who preferred analysis tended to do worse on the problem solving measure.

Major Analyses

The effects of experience and strategy use (instructed strategy or strategy preference) on problem solving performance were examined using analyses of covariance. The first analysis included experience and instructed strategy condition as independent variables with problem solving distance score as a dependent variable. Fluid and crystallized cognitive ability, analytical and intuitive cognitive style, and baseline problem solving performance were included in the analysis as covariates.

Strategy instructions and level of experience. Hypothesis 1 stated that problem solving performance depends on an interaction of strategy instruction and level of experience. First-year students were expected to perform better when using an intuitive strategy, and juniors were expected to perform better when using an analytical strategy. The hypothesized interaction of strategy instruction and level of experience was confirmed in the analysis of covariance, $F(2, 145) = 3.63$, $p = .03$. The results for the interaction are illustrated in Figure 1. The y-axis represents the distance score (D^2) from the consensus on the problem-solving measure. Higher values represent greater discrepancy from the consensus, and thus less successful performance.

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insert Figure 1 about here

Three covariates (baseline problem solving score, fluid intelligence, and analytical cognitive style) contributed significantly to the analysis. Zero-order correlations (see Table 1, appendix) showed that baseline scores and fluid intelligence scores were positively related to problem solving score, and higher analytical style scores were associated with worse problem-solving performance.

The interaction of strategy and experience was due primarily to the effect of the intuitive strategy instructions. First-year students in the intuitive condition (M = 9.85, SE = .67) scored significantly better than juniors in the intuitive condition (M = 11.89, SE = .63), $F(1, 145) = 5.02$, $p = .03$, $d = .44$[1]. Within the sample of juniors, there was a simple effect of strategy instructions, $F(2, 145) = 3.42$, $p = .04$. Juniors in the intuitive condition (M = 11.89, SE = .63) performed significantly worse than juniors in the analytical condition (M = 9.63, SE = .59), $p = .01$, $d = .33$. The difference between juniors in the intuitive condition and those in the control condition (M = 10.26, SE = .59) was marginal, $p = .06$, $d = .29$. Within the sample of first-year students, those using intuition (M = 9.85, SE = .67) scored non-significantly better than those in the control group (M = 10.74, SE = .54; d = .24) and those instructed to use analysis (M = 10.83, SE = .61; d = .30). Overall, the main effects of strategy instruction and level of experience were not significant in this analysis.

The same conceptual hypothesis was also examined among participants in the control group alone. This analysis examined the interaction of experience and strategy preference based on dichotomized cognitive style scores. The prediction was that the more-experienced participants scoring above the median on analytical cognitive style would score better than those without a preference for analytical thinking, and that less-experienced participants scoring above the median on intuitive cognitive style would score better than those who did not report being intuitive.

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insert Table 3 about here

A 2 x 2 analysis of variance was conducted for each dichotomized cognitive style variable to examine the effects of cognitive style and complexity on problem solving score. Each analysis included baseline problem solving score and cognitive ability as covariates. Adjusted means for this analysis are reported in Table 3. The predicted interactions of cognitive style and experience were not found for analytical or intuitive cognitive style, nor was the main effect of experience significant in this set of participants (all F's <1.0). Though the expected interaction was non-significant, the pattern of means for analytical cognitive style was in line with the hypothesis. Experienced participants with an analytical style tended to perform better than less-experienced participants with an analytical style (*d* = .51). Experienced students who reported a preference for analytical thinking tended to score better than their low-analytical counterparts (*d* = .44). However, contrary to the hypothesis, experienced students who reported a preference for intuition also performed substantially better than those who were less intuitive (*d* = .47), with highly intuitive juniors scoring as well as those who were highly analytical.

Discussion

Overall, the data provided support for hypothesis 1 and suggest modest support of hypothesis 2. Hypothesis 1 was confirmed in the significant interaction of experience and strategy instruction among all participants. More-experienced individuals were more successful when using the instructed analytical strategy than the intuitive one. In addition, more-experienced participants performed significantly worse when they relied on intuition than when they relied on their own preferred strategy (control group). Furthermore, analysis resulted in worse performance among less-experienced relative to more-experienced participants, and intuition resulted in worse performance among those with more experience relative to those with less. The expected benefit of intuition for less-experienced participants was not found. Performance among inexperienced participants was similar regardless of strategy instructions.

In order to explain this interaction, one must consider that these problems are relatively complex and involve the application of tacit knowledge that is difficult to articulate. Among those with a fair amount of experience, analysis aids practical problem solving because it focuses the individual on the information that he or she knows is key to the solution of the problem. When experienced participants rely on intuition, they may be distracted from that which is known to be relevant. Conversely, it is possible that when inexperienced participants attempt analysis, their performance suffers because they are likely to rely on irrelevant information during problem solving. However, the data in this study failed to detect a significant difference between performance of inexperienced participants in the analytical and intuitive conditions. These explanations are speculative, given that the study provides no evidence to confirm specifically what information was being considered during problem solving. Overall, the data support hypothesis 1.

Minimal support was found for hypothesis 2. There was no interaction of cognitive style and level of experience for either cognitive style. Yet, the pattern of means showed a medium effect of experience on problem solving among participants with an analytical cognitive style. This finding corresponds to the results for hypothesis 1. More experienced participants scored better when relying on an analytical strategy or their natural preference for an analytical approach to problem solving. The findings for intuitive cognitive style were inconclusive and did not support the hypothesis. The lack of statistical significance is not surprising, given that this hypothesis tested the effect of an individual differences independent variable rather than a manipulated strategy instruction as tested in hypothesis 1.

Notably, this study revealed no main effects of strategy instruction, cognitive style, or level of experience. As expected, neither analysis nor intuition was an optimal strategy for solving, whether the strategy was instructed or measured as cognitive style. However, the fact that participants with more experience were not more successful than those with less experience is problematic. Consequently, study 2 sought additional evidence for the hypotheses using a sample with a broader range of experience.

One caveat that must accompany the current results regards the content of the problems used. Many of the problems are social and interpersonal in nature, potentially limiting the generalizability of these findings to other domains. However, it is unclear to what extent these results may be influenced by the social nature of the items. In order to address this concern, study 2 was designed with a more diverse set of problems.

STUDY 2

The purpose of study 2 was to replicate the findings of study 1 with an improved experimental design. In this study, participants on a different campus with a broader range of expertise were recruited. Specifically, first-year undergraduates were recruited during the first two weeks on campus, and this sample was compared with junior and senior undergraduates who had been trained in the supervision of other undergraduates and worked as staff members of the Office of Residential Life. Further, additional problems were developed to sample a broader range of college-related problems, including those which were not social in nature. Finally, validation of the measure was established in two ways. First, items were selected for use based on validity ratings given by supervisors of undergraduate Residential Life staff members. Second, supervisor ratings of performance were sought for all participants in order to establish a correlation between rated performance and performance on the problem solving measure. The hypotheses for this study were the same as in study 1. Hypothesis 1 predicted an interaction of strategy instruction and experience, and hypothesis 2 predicted an interaction of cognitive style and experience.

Method

Participants

One hundred nineteen students (43 men, 76 women) from Illinois Wesleyan University participated in the study. First-year students (Mean age = 18.04, $SD = 0.37$) were recruited during their first two weeks of their first year of college ($N = 80$), and junior and senior students (Mean age = 20.77, $SD = 0.67$), selected for participation based on their experience as a Resident Assistant (RA) or Greek Peer Counselor (GPC), were tested throughout the academic year. RAs and GPCs are undergraduates who are responsible for students in residence halls or Greek houses at the University. For simplicity, all RAs and GPCs will be collectively referred to as Residential Life staff. All staff had received extensive training in dealing with everyday problems that face college students. The students in this sample had received between 120 and 180 hours of training and, on average, had worked for about a year or more in the position (RAs: $M = 1.66$, $SD = 0.58$, $N = 29$; GPCs: $M = 0.93$, $SD = 0.19$, $N = 7$). Staff interacted frequently with supervisors and received ample feedback regarding their performance, creating an environment conducive to the acquisition of tacit knowledge about problems in college life. All participants received class credit or a $10 gift certificate for their participation.

Materials

Additional CSTKI problems were developed to better represent a range of problems faced by college students. Eight members of the University Office of Residential Life who work full-time as supervisors of undergraduate staff members were recruited to evaluate the problems. The supervisors rated the problems to determine which items were most likely to discriminate between students with little experience and those with the kind of experience and training that is characteristics of juniors and senior Residential Life staff members. Based on this analysis, ten items were identified that received a rating of 3 ("somewhat more experienced than the average student") or above. These items were selected as valid measures of tacit knowledge in college life. Despite efforts to increase the number of items that were less social and interpersonal in nature, the majority of the ten highly-rated problems dealt with such themes (e.g., living with a thieving roommate, maintaining friendships). Scores were computed by calculating the Mahalanobis distance of each individual's response profile from the consensus of the experienced students in the sample ($\alpha = .82$). The means of the expert response profile for a sample item are provided in the appendix.

The same eight supervisors plus 50 staff members were recruited to give ratings of students who participated in the problem solving study with regard to performance in college life. Staff and supervisors rated the students on a scale of 1 (poor) to 7 (excellent) with regard to decision-making ability, academic skills, interpersonal skills, and ability to balance academics, work, and personal life. Because all raters were not equally familiar with all of the students in the sample, only those scores from raters who reported a competence level at or above the scale midpoint were included in the analysis. In an effort to establish some convergent validity for the problem solving measure, problem solving scores were correlated with the composite ratings. Overall, scores on the problem-solving items were correlated significantly with ratings ($r = -.40$, $p < .05$). This shows that participants whose problem-solving score was closer to the consensus of the experienced students were also rated as more capable in decision making and other related performance factors, confirming that the problems do capture a construct that is related to real-life success in college.

The remaining materials were a subset of those used in Study 1. In the interest of shortening the experimental session, participants were not tested on cognitive ability, and the Rational-Experiential Inventory (REI) was the sole measure of analytical and intuitive cognitive style (α = .88 and .90, respectively).

Procedure

The procedure for this study was identical to that of Study 1. Groups of participants were randomly assigned to an experimental condition: Analysis, Intuition, and Control. Participants completed the cognitive style measures prior to receiving instruction on problem solving.

Results

Preliminary analyses

Distance scores on the problem solving measure were examined for outliers, and all participants were retained (all scores were within three standard deviations of the mean). The effects of strategy and experience on each covariate were then tested in a series of analyses of variance. There were no main effects or interactions with respect to intuitive cognitive style, analytical cognitive style, or baseline problem solving scores. Based on responses on the Strategy Use Inventory (SUI), the manipulation was determined to have been successful (see Table 4). Participants used the strategy they were instructed to use. In order to strengthen our confidence in the manipulation, participants who reported not using the instructed strategy were removed from the primary analyses. This resulted in a sample of 101 participants (66 first-year students and 35 staff). There were 33 participants in the analytical condition, 25 in the intuitive condition, and 43 in the control group.

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insert Table 4 about here

Major analyses

In order to test for the interactive effect of strategy instruction and experience on problem solving, an analysis of covariance was conducted. The dependent variable was the mean score on problems which were rated as valid according to the supervisors. Independent variables were strategy instruction condition (analysis, intuition, or control) and level of experience (first-year students or staff). Covariates included baseline problem solving score, intuitive cognitive style (REI experiential scores) and analytical cognitive style (REI rational scores). These variables were included because of their correlation with problem solving scores (see Table 2A of appendix for correlation matrix). The adjusted means for the analysis of covariance are presented in Figure 2. Higher scores represent worse problem solving performance.

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insert Figure 2 about here

The results showed a main effect and an interaction, with no significant contribution from the covariates. The main effect of experience, $F(1, 92) = 4.80$, $p = .03$, showed that undergraduate staff members performed better overall ($M = 6.65$, $SD = 2.89$) than first-year students ($M = 7.51$, $SD = 2.21$), $d = .33$. This effect was qualified by an interaction of strategy and experience, $F(2, 92) = 3.26$, $p = .04$. Simple effects analyses showed that the analytical strategy was significantly more successful for experienced students than for first-year students, $F(1, 92) = 11.12$, $p = .001$, $d = 1.37$. Among experienced students, the simple effect of strategy condition was marginal, $F(2, 92) = 2.55$, $p = .08$. The trend showed that among experienced students, analysis led to better performance compared to those in the intuition condition ($d = .82$) and those in the control group ($d = .52$). Intuition led to slightly worse performance compared to those in the control group ($d = .13$). Among first-year students, there was no simple effect of strategy instruction; students in all three strategy conditions performed comparably, $F(2, 92) = 0.95$, $p = .39$.

In order to further investigate the reliability of this finding, participants in the control group were classified as either using an analytical or intuitive strategy based on their scores on the cognitive style measures. Analyses of covariance were conducted on problem solving scores using groups created via a median-split on REI scores. Cognitive style (above median vs. below median scorers) and experience (first-year students vs. staff) were independent variables and baseline problem solving was the covariate. Adjusted means are presented in Table 5.

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insert Table 5 about here

Among control participants, the interaction of analytical cognitive style and experience was found to be significant, $F(1, 38) = 6.91$, $p = .01$. Simple effects analyses showed that staff who were more analytical performed significantly better ($M = 6.03$, $SE = .68$) than staff with a low preference for thinking analytically ($M = 8.73$, $SE = 1.14$), $F(1, 38) = 4.16$, $p < .05$, $d = .75$. The difference between highly analytical ($M = 8.22$, $SE = .65$) and non-analytical ($M = 6.74$, $SE = .57$) first-year students was in the predicted direction, but the significance was marginal, $F(1, 38) = 2.98$, $p = .09$, $d = .87$. Comparing high-analytical participants at the two levels of experience, staff outperformed first-year students, $F(1, 38) = 5.51$, $p = .02$, $d = 1.24$. The same analysis conducted with intuitive cognitive style did not show the expected interaction of cognitive style and experience, $F(1, 38) = 0.60$, $p = .44$. Examining the pattern of means, there was a tendency for all participants to score relatively well, with the exception of first year students with low intuitive style. The effect of intuitive cognitive style among first-year students was large ($d = .96$). Notably, staff seemed to do well regardless of their preference for thinking intuitively. In addition, highly intuitive staff scored almost as well as those who were highly analytical.[2]

Discussion

These results confirm the effects found in study 1 and provide support for both hypotheses. The interaction of strategy instruction and level of experience was significant, as found in study 1, providing further support for hypothesis 1. Analysis led to the best performance among more experienced participants and the worst performance among those with little experience. The effect of strategy was most pronounced among experienced participants.

Examining the performance of participants in the control group, the pattern of means complemented those found among participants in the experimental conditions, providing support for hypothesis 2. Analytical participants with experience performed much better than experienced participants who did not prefer to think analytically. The opposite was true among less-experienced participants; less analytical thinkers performed better. While the interaction of intuitive cognitive style and experience did not reach conventional levels of significance, there was a large effect of intuitive preference among less-experienced participants. The results of the regression analysis provide converging evidence that higher preference for intuition and lower preference for analysis were associated with better problem solving. Among the staff, there was no evidence for an effect of intuitive cognitive style on problem solving. This suggests that intuition neither helped nor hurt their performance. It was the absence of analysis that led to poor performance among the experienced participants in this study.

The design of study 2 was significantly improved over that of study 1. Participants were sampled at a much broader range of experience, including students with two weeks of experience and others who had received extensive training in the problem-solving domain. In addition, the problems used were validated by the supervisors of the more-experienced participants. Problem solving scores were determined by distance from a relatively expert consensus, and those scores were moderately correlated with performance ratings.

GENERAL DISCUSSION

The results of both studies taken together provide substantial evidence for an interaction between level of experience and success of problem-solving strategy. Using analysis improved problem solving performance among experienced students and relying on intuition had a small, consistent benefit for inexperienced students. Notably, the findings of both studies showed that neither the intuitive nor the analytical strategy led to better performance than the other. The appropriateness of the strategy depended on the experience of the problem solver. This interaction can be explained in terms of the problem-solver's perception of the problem. An experienced individual sees the relevant information in a problem and knows how to analyze it in an explicit, logical manner. Relying on intuition may distract the expert from this critical information. In contrast, an inexperienced individual does not recognize the critical information in the problem and thus performs worse when relying on analysis. Instead, an intuitive, holistic approach may facilitate the solution of the problem for the novice by bringing to mind as much relevant information as possible. Additional research could help to confirm these explanations of the effects, perhaps by collecting think-aloud protocols or testing participants' memory for critical pieces of information after the problem-solving task is completed.

Even when no strategy instructions were given, individual differences in cognitive style had a similar impact on problem solving. Although some of the significance tests for the effects of cognitive style were marginal, this was likely due to the restricted sample size. Effect sizes demonstrated the substantial differences among means. It is difficult to detect effects of an individual-differences variable, especially on a general self-report measure of preferences that may or may not apply to the problems attempted in the study. Another source of inconsistency in these effects may have been the overlap between the median-split groups. While, it was not possible to compare groups which were exclusively high analytical and low intuitive with those that were high intuitive and low analytical due to restricted sample size, the regression analysis for first-year students provided some converging evidence in favor of the hypothesis. The fact that any effects were detected lends support to the primary conceptual hypothesis, and suggests that the effects may generalize to real-world problem solving in which no specific, pointed strategy is employed.

Implications

The results of this study may be easily generalized to social problem-solving behavior among undergraduates, and potentially individuals in other populations due to the high ecological validity of the materials. The problems used in this study refer to real-life problems encountered by a typical college student, and the instructional interventions were grounded in the context of everyday problem solving. The results of this study have implications for research on problem solving, expertise, and dual processes.

Problem solving. Researchers who aim to enhance practical problem solving and the acquisition of tacit knowledge needed for such tasks must consider that level of experience and will influence the type of training that will most benefit problem solvers. Research designs that can detect main effects alone may neglect to find meaningful interaction effects such as those found in this study. Other intervention studies seeking to teach problem-solving strategies or enhance decision-making should emphasize analytical strategies for individuals with more experience and may find a beneficial effect of a holistic, intuitive approach for novices.

The generalizability of these results may be limited by the content of the practical problems used. As mentioned previously, many of the problems used in both studies were social and interpersonal in nature. Notably, evidence from studies of problem solving and judgment that do not involve social elements (Berry and Broadbent's studies using a process control task and Wilson and Schooler's studies of judgments of strawberry jam) can be interpreted as support for these findings. In fact, social problems may simply be better suited to intuitive problem solving, not because they are social, but because they may be relatively more complex than non-social problems. In spite of the effort to broaden the scope of the problem domain in study 2, the actual problems selected for inclusion in the composite measure of problem solving were relatively social in nature. This effectively eliminated the opportunity to examine the effect of intuition on solving problems that differ in content. In future studies, the problem characteristics should be more varied more systematically to further examine the effectiveness of strategies on problems in various domains and with varying levels of complexity.

Expertise. These results imply that experts should use an analytical strategy for solving complex, practical problems. However, this may seem counterintuitive to many experts whose intuitions are highly accurate and based on decades of experience in the domain. In fact, some evidence from the present work showed that when allowed to follow their own preferred strategy, experienced participants who were highly intuitive performed as well as those who were highly analytical. Klein (1998) has shown that expert intuition can be very powerful for complex, high-stakes decision making. Some recent work in the medical decision-making literature suggests that experts' use of analysis may actually disrupt processing because their knowledge is encapsulated (Wimmers, Schmidt, Verkoeijen, & van de Wiel, 2005). The results of the work reported here appear to contradict such findings. However, there are two points to be made with respect to this apparent inconsistency. First, the definition of intuition must be clarified. Hill (1987-88) has made a distinction between holistic and inferential intuition. The novices in this study were instructed to use holistic intuition. In contrast, expert intuition is often considered a result of an automatization of previously-explicit processes, precisely the kind of intuition that is inferential. Second, it is arguable that the relative experts in study 2, the more experienced college juniors and seniors are not actually experts by the definition of the field. Compared to first-year students, the juniors and seniors with training may have a kind of intermediate expertise. In fact, it is difficult to determine who would qualify as an expert in the college life experience on any particular campus. Expertise is said to be achieved generally after ten years of experience in the domain (Chi, Glaser, & Farr, 1988), yet this level of experience is rarely achieved by Residential Life full-time supervising staff members let along undergraduate staff members. Future work should attempt to replicate findings in a sample for which clear experts and novices can be identified.

One theoretical model of the development of expertise can reconcile the current findings with evidence that experts do well with intuition. Baylor's (2001) U-shaped model of expertise and intuition proposes that intuition is used by both novices and experts, but that intermediate experts use a more analytical strategy. As these novices gain knowledge in the domain, they become better able to articulate their knowledge, and as they become intermediate experts who see the structure and logic of problems, they benefit from an analytical strategy. As this knowledge becomes part of an automatized expert schema, they become true experts who can rely on inferential intuition to make decisions and solve problems. Unfortunately, this theory could not be tested in the current study because it did not employ a sufficiently wide range of expertise, as noted above.

Synthesizing Baylor's theory with Hogarth's, we would predict a three way interaction of strategy, experience, and complexity. Baylor's U-shaped relationship between strategy and experience would also depend on complexity, and Hogarth's predicted interaction of strategy and complexity would also depend on experience. We would predict that even for true experts, extremely complex problems may not be easily analyzed, with intuition resulting in better performance. Similarly, intuition should be available to intermediate experts on relatively simple problems. Future work should test this hypothesized three-way interaction. It must be conducted in a domain in which there exist individuals with very little knowledge and individuals with highly automatized schemas using problems with varying levels of complexity. This design would test for the predicted interaction and for the distinction between holistic and inferential intuition.

Dual process models. This theoretical distinction between holistic and inferential intuition has implications for dual process models. Whereas this study highlights the benefits of intuitive processing, most researchers emphasize the limitations of the implicit, intuitive system. However, these studies criticize solely the heuristic, inferential nature of intuition. The holistic nature of intuition has strong advantages over analytical processing, especially when tasks are so complex that analysis leads to neglect of important information, where the whole is greater than the sum of its parts. Future studies in the dual process framework should attempt to distinguish between these two types of intuition and their influence on problem-solving and decision-making tasks.

This work contributes evidence to support Hogarth's (2005) current thought on dual processes. I have partially confirmed his predictions with regard to the interaction of processing mode and experience. These results provide evidence that relying on the deliberate system slightly improved performance among experienced individuals, which is in line with Hogarth's predictions. However, this study does not provide conclusive evidence that inexperienced individuals benefit from tacit processing. Future work should be done to test this theoretical prediction, perhaps with a stronger manipulation of processing mode, such as that used by Dijksterhuis. Additional research is needed to test Hogarth's prediction about the interaction of strategy and complexity. A recent study has provided evidence for this hypothesis in a different paradigm (Pretz & Zimmerman, 2007).

Conclusions

Practical problems are often ill-structured and involve high stakes. This study has demonstrated that the approach to solving such problems depends on a number of factors, including the experience and cognitive style of the problem solver as well as the complexity of the problem itself. Analysis is a good strategy to the extent that an individual can see the structure of a problem and identify the relevant pieces of information necessary for solution. However, this approach is not beneficial for individuals with little experience.

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Table 1

Study 1: Correlations Among Measures of Cognitive Style and Strategy Use.

	Subscale	1	2	3	4	5	6
1.	MBTI-thinking	--	-.22**	.11	-.37***	.25**	-.12
2.	MBTI-intuitive		--	.42***	.23**	-.10	.13
3.	REI-rational			--	.08	.12	.07
4.	REI-experiential				--	-.06	.37***
5.	Analytical SUI					--	.08
6.	Intuitive SUI						--

Note: **p < .01, ***p < .001.

Table 2

Study 1: Post-intervention Strategy Use Inventory by Condition.

Strategy	Analytical *M (SD)*	Intuitive *M (SD)*	Control *M (SD)*	ANOVA *F*(2, 161)
Imagine the situation very vividly.	4.37 (0.72)	4.56 (0.66)	4.23 (0.87)	1.36
Break the problem down into steps.	3.73 (1.05)	2.42 (1.04)	2.84 (1.00)	18.43***
View the problem from a variety of perspectives.	3.98 (0.97)	4.33 (0.69)	3.69 (1.04)	5.26**
Carefully define the problem.	4.28 (0.87)	3.33 (0.97)	3.41 (1.10)	12.81***
Rely on guesses or hunches.	2.60 (0.85)	3.88 (0.97)	2.85 (0.95)	27.98***
Monitor your problem-solving process.	3.48 (1.01)	2.92 (1.28)	2.47 (0.83)	13.76***
Skip the problem when you are stuck.	1.71 (0.93)	2.49 (1.25)	1.86 (1.12)	7.20**
Consider information that is implied about the situation that is not mentioned in the problem description.	4.09 (0.83)	4.41 (0.73)	4.11 (1.00)	1.17

Note: *p < .05; **p < .01, ***p < .001. Strategies rated 1-5 for frequency of use. Intuitive strategies are italicized; analytical strategies are underlined. Includes all participants.

Table 3

Study 1: Problem Solving Scores by Level of Experience and Cognitive Style Among Control Group Participants (adjusted means).

	First-years (n = 78)		Juniors (n = 78)	
	M	*SE*	*M*	*SE*
High Analytical Style (n = 27)	11.37	.78	10.05	1.00
Low Analytical Style (n = 32)	10.15	.77	10.24	.79
Low Intuitive Style (n = 22)	10.91	.86	10.84	1.14
High Intuitive Style (n = 37)	10.61	.75	9.91	.71

Note: Higher scores reflect worse problem-solving performance. Includes control group participants only. Groups based on median splits of cognitive style scores. Means are adjusted for baseline problem solving performance (*M* = 7.61), fluid intelligence (M = 15.36), and crystallized intelligence (20.86).

Table 4
Study 2: Post-intervention Strategy Use Inventory by Condition.

Strategy	Analytical *M (SD)*	Intuitive *M (SD)*	Control *M (SD)*	ANOVA *F*(2, 194)
Imagine the situation very vividly.	4.40 (0.70)	4.38 (0.68)	4.17 (0.90)	1.89
Break the problem down into steps.	3.71 (0.75)	2.47 (1.12)	2.89 (1.12)	24.88***
View the problem from a variety of perspectives.	4.14 (0.74)	4.16 (0.70)	3.50 (1.01)	13.92***
Carefully define the problem.	4.12 (0.66)	3.27 (1.10)	3.49 (0.96)	14.76***
Rely on guesses or hunches.	2.91 (1.06)	4.27 (0.73)	3.23 (1.16)	31.59***
Monitor your problem-solving process.	3.47 (0.84)	2.63 (1.15)	2.45 (0.98)	20.02***
Skip the problem when you are stuck.	1.55 (0.92)	2.14 (1.25)	1.48 (0.88)	8.00***
Consider information that is implied about the situation that is not mentioned in the problem description.	3.87 (0.93)	4.07 (0.78)	3.83 (0.85)	1.38

Note: ***$p < .001$. Strategies rated 1-5 for frequency of use.

Intuitive strategies are italicized; analytical strategies are underlined. Includes all participants.

Table 5

Study 2: Problem Solving Scores by Level of Experience and Cognitive Style Among Control Group Participants (adjusted means).

	First-years (n = 28)		Staff (n = 15)	
	M	*SE*	*M*	*SE*
High Analytical Style (n = 23)	8.22	.65	6.03	.68
Low Analytical Style (n = 20)	6.74	.57	8.73	1.14
Low Intuitive Style (n = 23)	8.29	.68	6.82	.72
High Intuitive Style (n = 20)	6.70	.59	6.50	1.18

Note: Higher scores reflect worse problem-solving performance. Includes control group participants only. Groups based on median splits of cognitive style scores. Means are adjusted for baseline problem solving performance (*M* = 7.72).

Figure Titles and Captions

Figure 1

Study 1: Problem solving performance depends on an interaction of strategy instruction and level of experience.

Note: Higher scores reflect worse problem-solving performance. Experimental conditions include “users” only. Means are adjusted for baseline problem solving performance, cognitive ability, and cognitive style. Error bars represent standard error.

Figure 2

Study 2: Problem solving performance depends on an interaction of strategy instruction and level of experience.

Note: Higher scores reflect worse problem-solving performance. Experimental conditions include “users” only. Means are adjusted for baseline problem solving performance and cognitive style. Error bars represent standard error.

Appendix

Sample problems

Sample problem including mean ratings for each response strategy across all participants in Study 1

You have decided to apply for an internship during the upcoming break, and want to ask one of your professors for a letter of recommendation. The professor you have in mind is teaching a fairly large class, and he does not know you very well. One day you run in to him in the coffee shop, where he is sitting with what you assume are his kids. Given this situation, rate the quality of the following options:

1	2	3	4	5	6	7
----+----	----+----	----+----	----+----	----+----	----+----	----+----
Extremely Bad	Very Bad	Somewhat Bad	Neither Bad Nor Good	Somewhat Good	Very Good	Extremely Good

__3.20____a) You decide that this is a good time to talk to him about the letter.

__5.51____b) You go up and greet him, reminding him of your name and what class you are in.

__4.13____c) You greet him and then start chatting with his kids.

__3.69____d) You nod but do not talk to him.

__3.19____e) You pretend you have not seen him. He probably does not want to deal with students outside of his workplace.

__2.93____f) You ask if you can sit down with him and his kids and talk about different things.

__5.12____g) You greet him and ask for an appointment with him the following day.

__2.44____h) You greet him and offer to buy him and his kids coffee or sodas.

Sample problem including mean ratings for each response strategy across experienced participants in Study 2

You are in a very challenging class that emphasizes class discussion as the primary basis for a grade. You consider yourself intelligent, curious about ideas, but very shy, self conscious and non-assertive. You learn from the discussion around you but it is very painful to feel that you have to contribute in order to get a good grade. You don't know anyone else in the class, and you don't know the professor. You have to get a good grade in this class to keep a decent GPA. Rate the quality of each of the following options:

1	2	3	4	5	6	7
----+----	----+----	----+----	----+----	----+----	----+----	----+----
Extremely Bad	Very Bad	Somewhat Bad	Neither Bad Nor Good	Somewhat Good	Very Good	Extremely Good

__3.39____a) Drop the class, and take another one that better fits your personality and one that you can succeed in.

__5.63____b) Force yourself to ask at least one question in class each day, even if you think your question might make you look stupid.

__5.18____c) Read about the discussion topic ahead of time and ask questions from the readings which you prepared in advance even if your questions don't fit in well with the discussion.

__2.64____d) Keep quiet. You can make up for what you lack in the discussion category by scoring well on quizzes and tests.

Table 1A

Study 1: Correlations Among Covariates and Problem Solving Scores.

	Subscale	1	2	3	4	5	6
1.	Fluid intelligence	--	.14	-.03	-.09	-.17*	-.22**
2.	Crystallized intelligence		--	.05	-.06	-.06	.02
3.	Analytical cognitive style			--	-.36***	.07	.17*
4.	Intuitive cognitive style				--	.02	.10
5.	Baseline problem solving score					--	.36***
6.	Score on CSTKI problems						--

Note: * p<.05, **p < .01, ***p < .001. Includes "users" and control participants only. Higher problem solving scores reflect worse performance.

Table 2A

Study 2: Correlations Among Covariates and Problem Solving Scores.

	Subscale	1	2	3	4
1.	Analytical cognitive style	--	-.09	.15	.22*
2.	Intuitive cognitive style		--	-.18	-.20*
3.	Baseline problem solving score			--	.49***
4.	Score on CSTKI problems				--

Note: * p<.05, ***p < .001. Includes "users" and control participants only. Higher problem solving scores reflect worse performance.

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[1] Cohen's *d* is reported for critical mean comparisons based on the unadjusted means. This method of calculation was chosen because no corresponding standard deviation was available for the adjusted means.

[2] In order to better understand the relative contribution of both cognitive style variables simultaneously, a hierarchical regression analysis was conducted for participants at each level of experience. Baseline performance was entered in the first block, and both cognitive style variables were entered simultaneously into the second block. Among first-year students, both intuitive (β = -.38, p = .03) and analytical (β = .36, p = .03) cognitive styles were significant independent predictors of problem solving performance. The best problem solving scores were associated with higher intuitive cognitive style and lower analytical cognitive style for the first-year sample. Together, the two cognitive style variables explained 31.8% of the variance in problem solving scores above and beyond that contributed by baseline scores. The same analysis was conducted for staff, but the results were not significant.