Cognitive Style and Flight Experience Influence on Confirmation Bias in Lost Procedures

Quan Xu; Mengyun Wang; Hongwei Wang; Bo Liu; Xuqun You; Ming Ji

BACKGROUND: Accident analysis and empirical research have shown that the decision-making process of pilots after becoming lost is adversely affected by confirmation bias; this constitutes a serious threat to aviation safety. However, the underlying mechanism of confirmation bias in the context of lost procedures are still unclear.

METHODS: This study used scenario-based map-reading tasks to conduct two experiments to explore the mechanism of confirmation bias in the lost procedures. In Experiment 1, 34 undergraduate students and 28 flying cadets were enrolled in a formal experiment to examine the effects of verbal-imagery cognitive style, experience level, and their interaction on confirmation bias. In Experiment 2, we further explored the influence of strategy as a core component of experience on confirmation bias with 26 flying cadets.

RESULTS: The study found that individuals were subject to confirmation bias in lost procedures. Visualizers (M = 0.78, SD = 0.75) were almost twice as likely to select the disconfirmatory features than verbalizers (M = 0.37, SD = 0.49). Visualizers exhibited a lower degree of confirmation bias than verbalizers, and experience helps verbalizers to reduce their degree of confirmation bias. The protective effect of experience mainly lies in individuals' choice of strategy.

DISCUSSION: Future aviation safety campaigns could be aimed at adopting a candidate selection process that focuses more on psychological attributes by testing for cognitive style, and enriching individual experience through adequate training. Such measures would reduce confirmation bias.

KEYWORDS: confirmation bias, aviation safety, individual differences, cognitive style, experience.

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Poor decision-making by the pilot is considered to be an important cause of aviation accidents or incidents.[17,19] Accident investigation has revealed that 56.5% of accidents are related to pilot errors in decision-making.[1] Confirmation bias—a tendency to seek out and interpret information in ways that conform to preexisting beliefs, expectations, or a hypothesis[22]—has been found to adversely affect the pilot's decision-making process.[16,20,32] This is particularly the case in the decision-making process after becoming lost, when the pilot incorrectly judges the current location of the aircraft due to the influence of confirmation bias; this constitutes a serious threat to aviation safety.[6] Although research to date has creatively applied confirmation bias to the aviation field and has proven the adverse effect of confirmation bias on the pilot's decision-making, there is a lack of in-depth research on the psychological mechanism influencing pilot confirmation bias. Considering the serious consequences that may be caused by confirmation bias, further exploration of the underlying mechanism behind confirmation bias in the aviation context is conducive to targeted prevention and intervention that could reduce pilots' decision-making errors.

Confirmation bias is a reflection of the limitations of human cognitive processing,[9] which has been proven to be widespread in all fields of real life, including politics,[36] medicine,[25] and sports.[18] Researchers have explored the cognitive mechanism of

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confirmation bias in depth and suggested that confirmation bias is mainly derived from the heuristics that people use when processing tasks.[9,31] Specifically, when individuals face complex problems in the decision-making process, in order to ease cognitive load, they will not carefully consider or comprehensively search for all available information, but will instead rely on cognitive shortcuts or heuristics to make decisions faster.[5] However, the use of heuristics may lead to confirmation bias and affect the accuracy of decision-making.[31,32] In everyday situations, the consequences of decision errors caused by confirmation bias may be relatively minimal. However, in a high-stakes industry, especially the aviation industry, the cost of making wrong decisions may be serious casualties and property losses.[32] The decision-making process of pilots after becoming lost is a typical example.

When pilots get lost, flight safety can be threatened in a number of ways, including air collisions, intrusion into restricted airspace, and controlled flight into terrain (CFIT). In order to avoid the risk of being lost, pilots are taught to use a fixed lost procedure to help them judge current location.[6] First, change the current course, fly in a circle, and maintain a safe altitude. Second, according to the initial flight plan, time, speed, and the last known location, guess the current approximate location and mark a circle at the corresponding location on the map, which is called the "circle of uncertainty". Finally, search for ground features from the cockpit and compare them with the "circle of uncertainty" marked on the map to check whether the plane is currently in this theorized location. Actually, the "circle of uncertainty" marked on the map is the hypothesis, and the ground features observed from the cockpit are the evidence used to test it. The pilot needs to use the evidence to constantly check whether the hypothesis is correct. Thus, this is a hypothesis testing process that is susceptible to confirmation bias.[35] Gilbey and Hill first explored confirmation bias in the lost procedures through three scenario-based map-reading tasks.[6] In each scenario task, subjects must choose one of three ground features that they consider the most useful to determine whether the "circle of uncertainty" marked on the map is correct, as pilots would do when lost. It was discovered that the subjects more frequently chose evidence that was consistent with their hypothesis than evidence that indicated that their hypothesis might be wrong, which indicated that they are susceptible to the effect of confirmation bias.

Cognitive style refers to individual habits of information processing, which are specifically manifested in the preference in perceiving, organizing, and remembering information.[3,26] The cognitive style integration model groups various cognitive styles into wholist-analytic and verbalizer-imager dimensions.[26,27] The model describes verbal-imagery cognitive style as a preference for processing information by either verbal (the verbal cognitive style) or imagery (the imagery cognitive style) processes when performing cognitive tasks.[12] Many studies have shown that the verbal-imagery cognitive style has an important influence on map or picture information processing, spatial navigation, and information searching behavior. A study examined the impact of cognitive styles on learning with texts and pictures, and showed that visualizers spend more time inspecting pictures than verbalizers, and the performance of visualizers was better than that of verbalizers when learning materials that combine texts and pictures.[11] Pazzaglia and Moè investigated the effects of different cognitive styles on learning performance with two types of maps,[24] and found that cognitive style significantly predicts learning performance on maps; visualizers have better learning performance on maps with rich visual features. Moreover, researchers have also found that verbal-imagery cognitive style affects individuals' performance at spatial navigation[3] and information searching behavior.[7] Visualizers tended to search in a general area and then narrow down the search, while verbalizers tended to search in a narrow area and then broaden the search. Also, visualizers spent less time than verbalizers on completing these tasks.

Actually, in the decision-making process after becoming lost, pilots need to continuously represent or process map information and spatial ground feature information.[6] Thus, this decision-making process has specific attributes involving the processing of map or picture information and spatial information. Therefore, intuitively, verbal-imagery cognitive style may play an important role in this decision-making process. Specifically, due to the difference in information processing preference, visualizers prefer to process map or picture information and spatial information more than verbalizers,[11,12] which may better match the characteristics of the decision-making task in lost procedures. The cognitive style integration model suggests that when the cognitive style matches the characteristics of the decision-making task, the subjective difficulty of the task for the individual will be reduced, thus reducing the cognitive load in the process of task execution.[26,27] Therefore, visualizers may perceive lower task difficulty and cognitive load than verbalizers when performing the decision-making task in lost procedures. According to the cognitive mechanism of confirmation bias, the reduction of cognitive load is beneficial to reduce the individual's reliance on cognitive shortcuts or heuristics in the decision-making process, thereby reducing the degree of confirmation bias. Based on these arguments, it was expected that visualizers would exhibit a lower degree of confirmation bias than verbalizers in lost procedures.

Furthermore, some studies have explored the influence of individual experience on confirmation bias, but no consensus has been reached. On the one hand, studies have pointed out that the superior knowledge possessed by experienced individuals enables them to quickly and effectively evaluate hypotheses and make correct decisions, while inexperienced individuals tend to grant too much weight to current hypotheses.[2,4] For example, compared with experienced criminal investigators, college students who lack experience in handling cases are more likely to accept the hypothesis provided by the examiner to make judgments, showing stronger confirmation bias.[2] Thus, the more experienced an individual is, the less likely they are to be affected by confirmation bias. On the other hand, some studies have found that individual experience cannot reduce the degree of confirmation bias, especially when faced with tasks with different attributes. Some research on confirmation bias in complex tasks has shown that experience not only

cannot help individuals avoid confirmation bias, but even leads to a higher degree of confirmation bias.[10,25] In a study on attitude change, a strong sophistication effect was found: the more experienced an individual was, the easier it was for them to defend their own attitude or opinion, showing a strong confirmation bias.[29]

It can be seen that the effect of experience on confirmation bias may be moderated by other factors, such as task difficulty or individual differences. Therefore, it is necessary to further explore the internal mechanism of the influence of experience on confirmation bias and analyze the potential moderating factors that may exist in it. For example, does the effect of experience on confirmation bias vary according to the different cognitive styles of individuals? In addition, a large number of studies have found that the differences between pilots with different experience are mainly manifested in their choice of strategy; in other words, strategy can be regarded as one of the main components of experience.[15,28] Strategy usually refers to a plan or approach of doing something to achieve a specific goal.[21] Many studies have shown that different strategies adopted by individuals to complete tasks affect the decision-making process and decision-making performance.[23,28] For example, based on experiments in a simulator, Schriver et al. found that different strategies affect the decision accuracy of pilots in fault diagnosis.[28] Similarly, when pilots get lost, the strategies they use to reason about their location may affect the decision-making process and decision accuracy, and appropriate strategies may help pilots reduce confirmation bias in the decision-making process.

To sum up, there is little research that deeply explores the underlying mechanism of confirmation bias in the aviation context. The aim of this study was to examine the impact of cognitive style, experience, and strategy on confirmation bias in lost procedures. Based on the theoretical perspective of the cognitive style integration model and the cognitive mechanism of confirmation bias, we made the following hypotheses. Visualizers may exhibit a lower degree of confirmation bias than verbalizers in lost procedures (Hypothesis 1). Experience may negatively affect confirmation bias in lost procedures, and this effect may be moderated by cognitive style (Hypothesis 2). Different strategies in the decision-making process may affect confirmation bias in lost procedures (Hypothesis 3).

EXPERIMENT 1

Methods

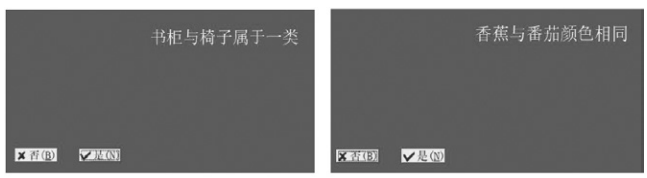
Subjects. A total of 62 subjects took part in the experiment, including 34 undergraduate students (M_{age} = 20.32, SD_{age} = 2.50) from Shaanxi Normal University, and 28 flying cadets (M_{age} = 20.68, SD_{age} = 0.67) from the Air Force Aviation University of China. All subjects were men, right-handed, and reported normal or corrected-to-normal visual acuity. The experiment was conducted between late February and early March 2019. Undergraduate students were randomly recruited on campus by distributing experimental recruitment information, and flight cadets were contacted and recruited with the help of a flight instructor. Additionally, the collection of flying cadet data was jointly completed by a flight instructor and a graduate student majoring in aviation psychology. To protect confidentially, only the age information of the flying cadets was collected. According to the flight instructor, all flying cadets participating in this experiment had at least 50 h of flying experience. Based on the effect size reported in the previous study (d = 0.69),[6] the power analysis using G*Power 3.1 showed that a sample size of 19 individuals was sufficient to achieve the power of 0.8, with alpha set at 0.05, two-tailed.

Furthermore, the subjects were preselected from a larger sample which consisted of 124 subjects (74 undergraduate students and 50 flying cadets) who had completed the Chinese version of the verbal-imagery subset of the Cognitive Style Analysis test (CSA-VI). According to the standard of the Chinese version of the CSA-VI,[13] subjects with a verbal-imagery ratio higher than or equal to 1.00 (imagery profile) and less than or equal to 0.86 (verbal profile) were invited to participate in the formal experiment. Finally, a total of 30 verbal subjects (17 undergraduate students and 13 flying cadets) and 32 imagery subjects (17 undergraduate students and 15 flying cadets) were screened out. The verbal subjects had an average verbal-imagery ratio of 0.75 (SD = 0.08), and the imagery subjects had an average verbal-imagery ratio of 1.10 (SD = 0.09). The study protocol was approved by the ethics committee of Shaanxi Normal University.

Materials

Cognitive style analysis. The Chinese version of the Cognitive Style Analysis test was revised by Li and Che on the basis of the original CSA test.[13,26] The verbal-imagery subset (CSA-VI) is composed of 6 practices and 48 formal trials; each trial is a statement, half of which are concept classification items, such as "bookcases and chairs belong to one category", while the other half are imagery classification items, such as "bananas are the same color as tomatoes". Each type of statement contains half correct and half incorrect items. As shown in **Fig. 1**, after each statement was presented on the task interface, subjects were required to judge whether the statement was correct or not by pressing one of two designated keys on the keyboard (if the answer is "No", press "B"; otherwise, press "N"), and subjects' response times (RTs) on each item were recorded.

CSA-VI takes the ratio of the RTs of concept classification items to the RTs of imagery classification items as an index for classification into verbal or imagery cognitive style. It was



Concept classification item Imagery classification item

Fig. 1. Task interface and sample stimuli of CSA-VI.

assumed that visualizers respond more quickly to imagery classification items because they are more likely to form color representations of objects (e.g., the color of bananas and tomatoes), whereas verbalizers respond more quickly to concept classification items that require verbal association between word meanings (e.g., bookcases and chairs).[26,27] Therefore, the low verbal-imagery ratio belongs to the verbal cognitive style, while the high ratio belongs to the imagery cognitive style. In the Chinese version of the CSA-VI,[13] a ratio lower than or equal to 0.86 indicates a verbal profile, whereas a ratio higher than or equal to 1.00 indicates an imagery profile, and a ratio between 0.86 and 1.00 indicates a mixed profile.

Scenario-based map-reading tasks. The investigation of confirmation bias in lost procedures in this experiment is based on the experimental paradigm of Gilbey and Hill,[6] in which scenario-based map-reading tasks were used as experimental material. The original English version of this material was provided by Professor Gilbey, and then we translated the English description of each scenario into Chinese and made a small amount of revision to make it more suitable for Chinese subjects. The experimental task consists of three scenarios: motorcycle, yacht, and light aircraft. The three scenarios were similar in nature, but the superficial descriptions between the scenarios were different. To complete the task in each scenario, subjects were asked to imagine that they had lost their way and had an urgent need to reorient themselves (similar to the situation in which pilots get lost in flight). In each scenario task, subjects were provided with a text description of the scenario and a map describing the area of the scenario, with a compass rose on each map. The textual description of the scenario provided sufficient information to simulate people in a lost situation and to guide subjects to form a hypothesis about the possible location. For example, subjects imagined themselves as a passenger on a lost yacht whose captain had fallen overboard (yacht scenario), or imagined themselves on a cross-country flight in a light aircraft whose pilot was unsure of his location (light aircraft scenario).

As a necessary condition of the experimental design, the hypothetical location (the circle marked location) in each scenario map in this study was drawn in advance by the researcher. Each circle location was a false hypothesis: the circle marked location was not the actual location. In addition, subjects were told that they could see three ground features from their actual location (e.g., "the main road and rail run directly side-by-side below you", listed after each scenario), and that they needed to choose the one most useful feature to determine whether they were really in the circle marked location on the map. In other words, the ground features were used to test the authenticity of the hypothetical map location.

Of the three ground features given in each scenario, two features appeared both in the hypothetical location on the map and also in the actual location. These two features can be used as evidence to support the hypothetical location is correct, and choosing either of these features indicates that individuals are overly dependent on evidence consistent with their assumptions about where they believe they are (positive tests of the hypothetical location). Therefore, these two features were regarded as confirmatory choices (e.g., "you can see small aircraft landing and taking off close behind the town" and "you can see a wide river mouth" in the yacht scenario). Meanwhile, the third feature did not appear in the hypothetical location on the map and only appeared in the actual location. This feature can be used as evidence to support the hypothetical location is wrong and the selection of this feature indicates that the individual carried out a negative test on the hypothetical location. Thus, this feature was regarded as a disconfirming choice (e.g., "there appears to be a high bush-clad peak behind the town, directly to your north" in the yacht scenario). Furthermore, selecting the disconfirming choice could determine that the hypothetical location was wrong and so it was the most useful feature for subjects to use in deciding whether they were in the circled area. According to the experimental paradigm of Gilbey and Hill,[6] if the rate of selecting the disconfirming choice is significantly lower than would be expected by chance, it indicates that individuals are subject to confirmation bias.

Apparatus. All tests and experimental tasks were performed on a computer, specifically a Dell Inspiron 5559 laptop (Intel Core i7-6500U) with a 15.6-inch screen and 1366 × 768 resolution. In addition, the presentation of scenario-based map-reading task materials, program running, and data collection in the formal experiment of this study were all completed in iMotions 6.2 software, which is a comprehensive desktop-based synchronization research platform for psychology and human factors.

Procedures. In order to screen out verbalizers and visualizers, all subjects first completed the CSA-VI on the computer and the verbal-imagery ratio of each subject was recorded. After each subject completed the CSA-VI, the experimenter immediately checked the test results to determine whether the subject met the criteria for participating in the formal experiment. According to the standard of the Chinese version of the CSA-VI,[13] the experimenter invited subjects with a ratio higher than or equal to 1.00 (imagery profile) and less than or equal to 0.86 (verbal profile) to participate in the formal experiment.

In the formal experiment, the subjects were first asked to spend 5 min learning the map symbols on the paper with detailed instructions and became familiar with the meanings of the different symbols. Next, the experimenter introduced the whole experimental process and precautions to the subjects. Once the subjects understood the experimental process and felt familiar with the map symbols, they clicked "Next" at the bottom of the task interface to complete the experimental tasks for each scenario in turn. Each scenario task was presented in two interfaces. The first interface presented the text description of the scenario and the second interface presented the map and three features. When solving the task of each scenario, the subjects used the mouse to click the corresponding feature on the second interface of the scenario to complete the selection. According to the experimental paradigm of Gilbey and Hill,[6] subjects were given no time limit to solve each scenario task. Overall, all subjects were able to complete the task in about 15 min.

Statistical analysis. SPSS 22.0 was used to analyze all data in this study. The total number of disconfirming choices chosen by the subject across the three scenarios was used as the dependent variable index. A single sample *t*-test (two-tailed, test value = 1) was conducted to examine whether individuals were subject to confirmation bias in lost procedures. Furthermore, a 2 cognitive style (verbal and imagery) × 2 experience (inexperienced and experienced) analysis of variance (ANOVA) was performed to examine the effects of verbal-imagery cognitive style and experience level and their interaction on confirmation bias in lost procedures. Also, simple effect analysis was performed to inspect the nature of the interaction between cognitive style and experience.

Results

The analysis of the performance of all subjects in three scenario-based map-reading tasks showed that subjects made 0 ($N = 31$), 1 ($N = 27$), 2 ($N = 3$), or 3 ($N = 1$) disconfirming choices. In other words, the disconfirmatory feature was chosen only 19.35% of the time and half of subjects made no disconfirming choice. The mean number of disconfirmatory features chosen by the subjects was 0.58 and the standard deviation was 0.67. Visualizers (M = 0.78, SD = 0.75) were almost twice as likely to select the disconfirmatory features than verbalizers (M = 0.37, SD = 0.49). For the sake of comparison, if they had answered randomly, the average number of disconfirming choices would be 1. Based on this, a single sample *t*-test was conducted (two-tailed, test value = 1) on the total number of disconfirming choices. The result was significant [$t(61) = -4.954$, $P < 0.001$, $d = 0.54$, 95% confidence interval (CI) = −0.59, −0.25], indicating that the actual performance of subjects was worse than the performance expected from random answers. Thus, subjects were more likely to use confirmatory evidence than disconfirmatory evidence to test their location.

ANOVA conducted on the total number of disconfirming choices showed that the main effect of cognitive style was significant [$F(1, 58) = 5.646$, $P < 0.05$, $\eta^2_p = 0.089$]. The number of disconfirming choices of subjects with an imagery profile was significantly higher than that of subjects with a verbal profile. The main effect of experience was not significant [$F(1, 58) = 2.375$, $P > 0.05$, $\eta^2_p = 0.039$]. The two-way interaction between cognitive style and experience was also significant [$F(1, 58) = 4.474$, $P < 0.05$, $\eta^2_p = 0.072$].

As shown in **Fig. 2**, further simple effect analyses showed that, for the verbal cognitive style, there were significant differences in the number of disconfirming choices of subjects with different experiences [$F(1, 58) = 6.432$, $P < 0.05$, $\eta^2_p = 0.1$] and the number of disconfirming choices of the flying cadets (M = 0.69, SD = 0.48) was significantly higher than that of the undergraduate students (M = 0.12, SD = 0.33). For the imagery cognitive style, there was no significant difference in the number of disconfirming choices of subjects with different experiences [$F(1, 58) = 0.171$, $P = 0.68$, $\eta^2_p = 0.003$].

Discussion

The results of Experiment 1 indicated that the subjects were influenced by confirmation bias in lost procedures, which is consistent with the work of Gilbey and Hill.[6] We also found that individuals with an imagery profile had a lower degree of confirmation bias than individuals with a verbal profile. This finding echoes the related findings related to verbal-imagery cognitive style.[3,11,24] Furthermore, the effect of experience on confirmation bias was significant in the verbal cognitive style group, but not in the imagery cognitive style group. These results suggest that the effect of experience on confirmation bias is moderated by cognitive style, and experience has a protective effect against confirmation bias in individuals with a verbal cognitive style.

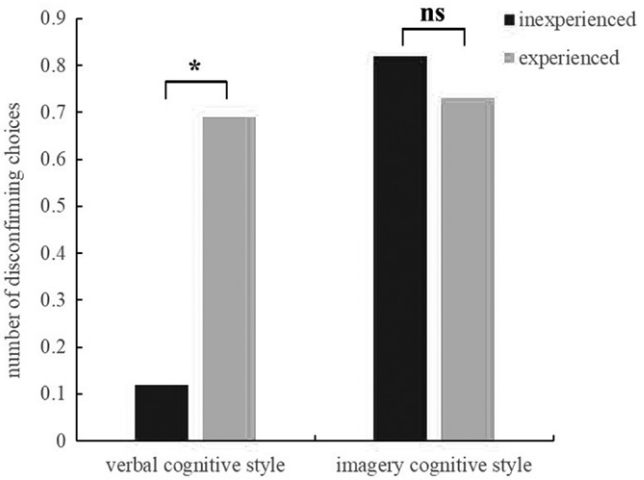


Fig. 2. The total number of disconfirming choices as a function of cognitive style and experience (ns indicates $P > 0.05$, * indicates $P < 0.05$).

Studies have shown that the differences between pilots with different levels of experience are mainly manifested in strategy.[15,28] Therefore, in order to further explore what components of experience have an effect on confirmation bias, we examined the influence of strategy on confirmation bias in the following experiment.

EXPERIMENT 2

Methods

Subjects. In this study, 26 male flying cadets from the Air Force Aviation University of China participated ($M_{age} = 20.89$, $SD_{age} = 0.65$). The experiment was conducted in mid-March 2019, and the subjects in this experiment did not participate in Experiment 1. All subjects had at least 50 h of flying experience, were right-handed, and reported normal or corrected-to-normal visual acuity. They were all contacted and recruited with the help of a flight instructor.

Procedure. A mixed method approach combining an experimental method and a survey method was used to explore the influence of strategies on confirmation bias. In this experiment, subjects first completed three scenario-based map-reading tasks in turn. The procedure for completing these tasks was the same as Experiment 1. After subjects completed all experimental tasks, they were asked about their decision-making strategies in

completing the tasks. The same question was employed in all cases: "Why do you think the feature you selected was the most useful? Please briefly describe the reason or basis for your choice, which can be specifically explained in conjunction with one of the scenarios." The question was conducted in the form of a paper-and-pencil survey, and screenshots of the task interface were printed on a separate sheet of paper to help subjects with accurate recall.

Statistical analysis. A thematic analysis was used to sort and analyze all the survey materials from the subjects[30] so as to determine the decision-making strategy used by each subject to test the hypothetical location. This was carried out in two stages. First, by reading all the text materials obtained from the survey, common themes were determined and different types of decision-making strategies were classified. Second, the content of each subject's survey was carefully evaluated to find keywords related to the identified themes, and the survey content was classified accordingly. The first author led the analysis, and the second and third authors assisted and checked throughout the process. Furthermore, one-way ANOVA were performed using SPSS 22.0 to examine the effect of the strategy on confirmation bias in lost procedures. The dependent variable was the total number of disconfirming choices chosen by the subject across the three scenarios.

Results

Subjects made 0 ($N = 14$), 1 ($N = 9$), 2 ($N = 1$), or 3 ($N = 2$) disconfirming choices. As a whole, the disconfirmatory feature was chosen 21.79% of the time and more than half (53.85%) of subjects made no disconfirming choice. The mean number of disconfirmatory features chosen by the subjects was 0.65 and the standard deviation was 0.89. In general, this study identified three common decision-making strategies through thematic analysis, as follows:

Strategy 1: Select features according to the attributes of the target object. The subjects using this strategy ($N = 9$) mainly focused on the attributes of the target object (such as a mountain) mentioned in the feature options, such as the distance, the size of the target object, etc., and believed that the attributes of the target object were most helpful for them to determine their own location. For example, the subjects answered, "the high mountain is a big and obvious target, which can help me to judge the location easily", and "I exclude clues that are far away from me, because the distance is too far to make accurate judgments".

Strategy 2: Look for features that confirm the hypothetical location. The subjects using this strategy ($N = 11$) mainly focused on the features that can prove that the assumed location is the correct location. For example, the subjects answered, "the airport is exactly north, and I saw planes taking off and landing also exactly north", and "I can see a railway at the current position, and there is a railway and its branch lines in the white circle".

Strategy 3: Exclude features that appear repeatedly in multiple places on the map. The subjects using this strategy ($N = 6$) mainly used the elimination method to focus on multiple recurring features in the map. For example, the subjects answered, "there is more than one wide river mouth, and there is only one airport on the entire map, so it can be used as the most useful feature", and "I first exclude features that also appear elsewhere on the map, and then make a choice".

The mean and standard deviation of disconfirmatory features chosen by the subjects in the three different strategies are as follows: strategy 1, M = 0.56, SD = 0.53; strategy 2, M = 0.09, SD = 0.30; strategy 3, M = 1.83, SD = 0.98. One-way ANOVA test results showed that different strategies had a significant impact on the total number of disconfirming choices [$F(2, 23) = 17.211$, $P < 0.001$, $\eta^2_p = 0.599$]. Further multiple post hoc comparison results showed that strategy 3 was significantly different from strategy 1 ($M_D = 1.278$, $P < 0.001$, 95% CI = 0.64, 1.92) and strategy 2 ($M_D = 1.742$, $P < 0.001$, 95% CI = 1.12, 2.36), while strategy 1 and strategy 2 were not significantly different ($M_D = 0.465$, $P = 0.092$, 95% CI = −0.08, 1.01).

Discussion

In Experiment 2, we identified three strategies used by the subjects in completing the scenario-based map-reading tasks. The results showed that different strategies had a significant impact on confirmation bias, which is somewhat similar to the findings of Schriver et al.[28] They showed that better attentional strategy could help pilots' decision-making. Specifically, we found that strategy 3 significantly reduced the degree of confirmation bias compared to strategy 1 and strategy 2. This may be due to the fact that this strategy helps individuals quickly and effectively eliminate the interference of irrelevant information and complete the processing of key information.

OVERALL DISCUSSION

The primary purpose of this study was to explore the impact of cognitive style, experience, and strategy on confirmation bias in lost procedures. The results showed that the individuals in this study were subject to confirmation bias in lost procedures. Cognitive style was found to affect confirmation bias: visualizers had a lower degree of confirmation bias than verbalizers. Moreover, experience helps individuals with verbal cognitive style to reduce the degree of confirmation bias and the protective effect of experience mainly comes from the specific strategies adopted by individuals. This study makes contributions to the current pilot confirmation bias and aviation safety research through exploring the underlying mechanism of confirmation bias in lost procedures. The results of this study may help to prevent and intervene in the confirmation bias of pilots so as to reduce the pilots' decision-making errors.

This study simulated lost procedures and used three scenario-based map-reading tasks to explore this decision-making process after becoming lost. It was found that individuals were subject to confirmation bias in this decision-making process, in that they demonstrated a preference for using confirmatory evidence rather than disconfirmatory evidence to establish their location. However, the use of disconfirmatory evidence would help pilots quickly determine that their hypothetical

location is not the actual location after they get lost, which may prevent them from putting themselves in greater danger and reduce the likelihood of an accident. Our results are consistent with the work of Gilbey and Hill,[6] again proving the negative impact of confirmation bias on aviation decision-making in the context of Chinese culture. Previous studies have shown that confirmation bias is widely present in all areas of human life.[18,25,36] This study further demonstrates the universality of confirmation bias in human decision-making. Compared with decision-makers in other fields, pilots lack sufficient time and cognitive resources to search and process the required information due to the high level of uncertainty and cognitive load in aviation situations,[34] making pilots more susceptible to confirmation bias.[31,32] The consequences of this kind of influence are more harmful and socially influential than the consequences of decisions in other areas. Thus, the results of this study tell us that confirmation bias in pilot decision-making is an important factor affecting flight safety, and this problem should be given substantial attention by managers and researchers.

Based on the specific attributes of the decision-making task after becoming lost, we focused on the influence of verbal-imagery cognitive style on confirmation bias, and found that visualizers exhibited a lower degree of confirmation bias than verbalizers, thus supporting Hypothesis 1. A plausible explanation for this finding would be that compared to individuals with a verbal profile, individuals with an imagery profile show significant advantages in map or picture information processing and spatial navigation.[3,11,24] The decision task in lost procedures involves the processing of map information and spatial information, so the task is easier for individuals with an imagery profile. Their advantage in information processing on this task may save more cognitive resources and reduce cognitive load. According to the cognitive mechanism of confirmation bias, when cognitive resources are sufficient and cognitive load is low, individuals can process more information comprehensively and reduce the use of cognitive heuristics, which may reduce the degree of confirmation bias.[5,31,32] Therefore, this finding extends the research on individual differences in confirmation bias and suggests that, although confirmation bias is a common phenomenon in human decision-making processes, it influences different individuals to different degrees.

Although our study did not find a significant main effect of experience on confirmation bias, we did find that the interaction between experience and cognitive style had a significant effect on confirmation bias. Specifically, the effect of experience on confirmation bias was significantly different in the verbal cognitive style group, but not in the imagery cognitive style group. These results suggest that experience has a protective effect on the confirmation bias of individuals with a verbal cognitive style. Thus, Hypothesis 2 was partially supported. A possible reason for these findings is that, on the one hand, experienced individuals have superior knowledge or strategies that enable them to evaluate hypotheses quickly and effectively and to make correct choices and decisions.[2,4] Consequently, although individuals with verbal cognitive style have an inherent processing disadvantage in this decision-making task, this processing disadvantage may be significantly compensated by rich experience. On the other hand, although individuals with imagery cognitive style have inherent processing advantages in this decision-making task, it is difficult to completely eliminate confirmation bias through experience.[29] This means that the protective effect of experience is not fully and significantly reflected in individuals with imagery cognitive style.

In order to further explore why experience has a protective effect against confirmation bias in individuals with a verbal cognitive style, we further explored the effect of strategy as a core component of experience in Experiment 2. The results showed that there were three main strategies the subjects used to complete the scenario-based map-reading tasks. Strategy 3 (exclude features that appear repeatedly in multiple places on the map) significantly reduced the degree of confirmation bias compared to strategy 1 and strategy 2. Therefore, these results supported Hypothesis 3 and further explained the findings of Experiment 1.

The adverse effects of confirmation bias on decision-making in flight have been confirmed in empirical research[6,32] and accident investigation reports.[20] Therefore, the question of how to reduce or eliminate confirmation bias from pilots' decision-making is of great significance to aviation safety, and a major practical problem to be solved in aviation safety management. Researchers have tried to reduce the confirmation bias in pilots' weather decisions using a debiasing technique called "considering the alternative", but the results showed that the debiasing technique was not an effective intervention against confirmation bias.[33] Most studies using debiasing techniques to reduce cognitive bias have garnered similar results.[14]

Given that this is the case, research on the influence mechanism of pilot confirmation bias may be another potentially effective way to explore how to reduce confirmation bias. If one can deeply understand the generation mechanism and potential influencing factors of confirmation bias, then one may be able to provide effective technical support for pilots' targeted psychological selection and training from the perspective of practical intervention, so as to reduce confirmation bias. This study is based on this purpose and background, and its results provide some potential measures and suggestions for intervention against confirmation bias in the decision-making process after becoming lost.

First, stable psychological variables can be used as an evaluation index for pilot psychological selection to reduce the impact of confirmation bias. The results of this study indicate that the verbal-imagery cognitive style has a significant impact on confirmation bias, and the cognitive style, as a reflection of innate personality differences in information processing, is stable.[26] Thus, one might use verbal-imagery cognitive style as an evaluation index for the psychological selection of pilots and reduce the influence of confirmation bias by selecting individuals with an imagery cognitive style. Second, one might use pilot training to reduce the influence of confirmation bias, targeting malleable psychological variables. The results of this study show that experience may help individuals with verbal cognitive style to reduce their degree of confirmation bias in the decision-making process after becoming lost, and the protective effect of experience mainly comes from the strategies adopted

by individuals. This indicated that we can reduce the impact of confirmation bias through adequate training of pilots, especially through strategy training to improve task-related experience. However, we need to combine the characteristics of pilots' different cognitive styles in training, and focus on increasing the training of pilots with verbal cognitive style, so as to improve training efficiency.

Despite the encouraging findings of this study, several limitations should be noted when interpreting its results and contemplating future research. First, in this study, scenario-based map-reading tasks were used as the experimental material. Although these tasks to a large extent simulated the decision-making process in lost procedures, they were still different from the decision-making process in an actual flight situation, which may affect the ecological validity of the conclusion to some extent. In an actual flight situation, pilots need to determine their location while controlling the aircraft,[6] which would further increase cognitive load and lead pilots to rely more on heuristics.[31] Therefore, in future research, a portable eye tracker can be matched with a flight simulator with a high simulation degree for further research, so as to make conclusions with more ecological validity. Second, this study only explored the mechanism of confirmation bias in one kind of flight situation, that is, the lost situation, and this is somewhat one-sided. Future research can further explore the influence mechanism of confirmation bias in other flight situations, such as weather-related decision-making situations,[32] and establish a corresponding theoretical model, so as to provide more comprehensive theoretical guidance for the prevention of confirmation bias in flight. Finally, in this study, only undergraduate students and flying cadets were selected to distinguish between experienced and inexperienced subjects. In the future, more experienced pilots should be selected and compared with inexperienced or low-experienced subjects to further verify our research results.

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