Metacognition and Decision-Making

Preeti Vijayakumar
Human Factors in Information Design, Bentley University
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Dr. William Gribbons
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Metacognition refers to one's knowledge concerning one's own cognitive processes (Flavell, 1979). It has evolved as an adaptive mechanism for humans to navigate complex environments. This ability plays a crucial role in decision-making. With the very small budget of attention we have, prioritising what we'll be attending to is a crucial part of the decision-making process, allowing individuals to assess their knowledge, set goals, evaluate risks, and adjust strategies (Simon, 1993). Metacognition is directly related to our performance and plays a crucial role in maintaining our engagement with a task. The higher our engagement with a task and level of expertise, the better our performance, which, in return, sustains engagement (Thayer, 1989).

Interaction designers can leverage this understanding of metacognition to design products that can sustain engagement and support decision-making. This paper describes the various stages of metacognition and its role in decision-making including theories and effects of heuristics and biases, followed by a design review of an airport assistant mobile application.

Process of Metacognition

Metacognition can be described as "thinking about thinking or a person's cognition about cognition" (Wellman, 1985). It involves reflecting on and evaluating one's knowledge, skills, and strategies, as well as making judgments about how to approach tasks and solve problems. Integral to human cognition, it relies on neural networks involving the prefrontal cortex, hippocampus, and other brain regions associated with memory, attention, and executive functions (Shimamura, 2000).

Metacognition encompasses knowledge about one's cognitive processes and the regulation of these processes. This includes understanding declarative (knowing about things), procedural (knowing how to do things), and conditional knowledge (knowing why and when), as well as engaging in regulatory skills like planning, monitoring, and evaluation (Moshman, 2018)

Metacognitive monitoring involves observing one's cognitive processes, while metacognitive control entails making decisions based on this monitoring (Perfect & Schwartz, 2002). This process involves selecting, maintaining, updating, and rerouting cognitive processes (Shimamura, 2000). Control processes are revealed by the behaviors a person engages in as a function of monitoring.

Flavell (1979) described four classes of phenomena whose actions and interactions shape cognitive monitoring - metacogntive knowledge, experience, goals and strategies. *Metacognitive knowledge*, refers to the knowledge base concerning one's cognitive processes and learning strategies. It encompasses factual information about how individuals learn, the factors influencing learning effectiveness, and the existence of cognitive biases (Flavell, 1979; Moritz & Lysaker, 2018). *Metacognitive experience*, constitutes the in-the-moment, subjective phenomena associated with cognitive activity. They are conscious reflections on cognitive processes and can prompt changes in goals, knowledge, and strategies. *Goals (or tasks)* refer to the objectives of a cognitive enterprise, and *actions (or strategies)* refer to the cognitions or other behaviors employed to achieve them (Flavell, 1979). Additionally, *metacognitive awareness* bridges the gap between knowledge and experience. It represents the conscious application of metacognitive knowledge to interpret ongoing experiences and subsequently adapt cognitive processes. Essentially, it involves leveraging one's understanding of learning to make real-time adjustments in response to internal states (Perfect & Schwartz, 2002). Three “essential” cognitive stages are planning, monitoring, and evaluation (Moshman, 2018). These could occur before cognitive activities (planning), during activities (monitoring), or after activities (evaluating) (Akturk & Sahin, 2011). *Planning* involves setting goals, selecting strategies and deciding how to approach a task. *Monitoring* entails awareness of progress, error detection and observing and assessing one's performance, understanding what one knows and doesn't know, and recognizing when additional information or strategies are needed. *Evaluation* involves critically reflecting on the effectiveness of one's cognitive processes and strategies, determining their success or failure, and identifying areas for improvement. *Regulation* encompasses the use of cognitive strategies to control and adjust one's thinking, such as setting goals, planning approaches, allocating resources, and monitoring progress. Throughout this process, individuals engage in self-awareness, self-assessment, and self-regulation to optimize their cognitive performance and achieve their goals (Brown, 1978; Norman, 2016).

Notably, experts and novices demonstrate distinct metacognitive states and processes. Experts possess richer and more organized domain-specific knowledge stored in long-term memory, enabling them to engage in more sophisticated metacognitive strategies (Veenman et al, 2006). Novices, on the other hand, often rely on simpler strategies and have less developed metacognitive skills. These differences impact decision-making, as experts tend to exhibit more accurate self-assessment and goal-setting abilities, leading to more efficient problem-solving and learning outcomes (Pretz, 2008). Interaction designers must account for these variations in expertise when designing interfaces. For experts, interfaces should offer advanced features and customization options to accommodate their higher levels of knowledge and skill. For novices, interfaces should provide guidance, feedback, and scaffolding to support their learning & development of metacognitive skills (Mosier & Fischer, 2010).

The concepts of cognition and metacognition are different although they are related to each other. While metacognition is necessary to understand how a task will be performed, cognition is required to fulfill a task. Metacognition is a basic requirement for cognitive effectiveness (Schraw, 2009).

Decision-Making

Decision-making is a critical skill that involves identifying and prioritizing problems, generating alternatives or potential solutions, and evaluating and selecting among them (Tversky & Kahneman, 1981; Simon, 1993). This is essential for individuals navigating complex environments, requiring them to allocate attention and resources effectively. Metacognitive monitoring and decision-making mutually influence each other through iterative feedback loops (Perfect & Schwartz, 2002).

Flexibility in decision-making denotes the capacity to adjust and revise one's choices or approaches when confronted with fresh data, evolving situations, or unanticipated occurrences. This adaptability is influenced by task complexity, options, outcomes, time constraints, and cognitive, emotional, and experiential factors, alongside personal experiences, education, and cognitive development (Cubitt et al., 1993). Expertise influences decision-making, with experts demonstrating superior skills compared to novices (Flavell, 1979). Long-term memory stores experiences, aiding decision-making via pattern recognition and schema activation (Mosier & Fischer, 2010). Working memory holds information temporarily, supporting reasoning and problem-solving during decision-making (Baddeley, 2003).

Theories

Maximization theories, like expected value and expected utility, suggest decision-makers seek to maximize value or utility. *Expected value theory* calculates the payoff of each option based on outcome probabilities, while *expected utility theory* assess risky prospects by compaing expected utility values (Fishburn, 1970). In contrast, *prospect theory* by Kahneman and Tversky proposes that decisions are influenced by subjective perceptions of gains and losses and not objective outcomes, thus leading to risk-averse behavior with gains and risk-seeking behavior with losses (Kahneman & Tversky, 1979). This theory challenges rational assumptions and introduces the *framing effect*, which shows how the presentation of options can alter preferences (Kahneman & Tversky, 1979). *Bounded rationality* theories, pioneered by Herbert Simon, acknowledge cognitive limitations, such as such as limited information processing and time constraints, and advocate for satisficing rather than optimizing outcomes (Simon, 1955).

Rational theories aim for optimization but may be impractical in uncertain contexts, leading to the adoption of nonrational strategies, such as heuristics, which simplify decision-making by ignoring certain information (Gigerenzer & Gaissmaier, 2015).

Heuristics are decision-making strategies that prioritize speed and efficiency by simplifying information processing. They consist of three main components: search rules, stopping rules, and decision rules (Gigerenzer & Gaissmaier, 2015). However, reliance on heuristics can lead to cognitive biases, which divert decision-makers from optimal choices (Das & Teng, 1999). Tversky and Kahneman (1974) identify three key heuristics—representativeness, availability, and adjustment and anchoring—that contribute to various cognitive biases (Das & Teng, 1999).

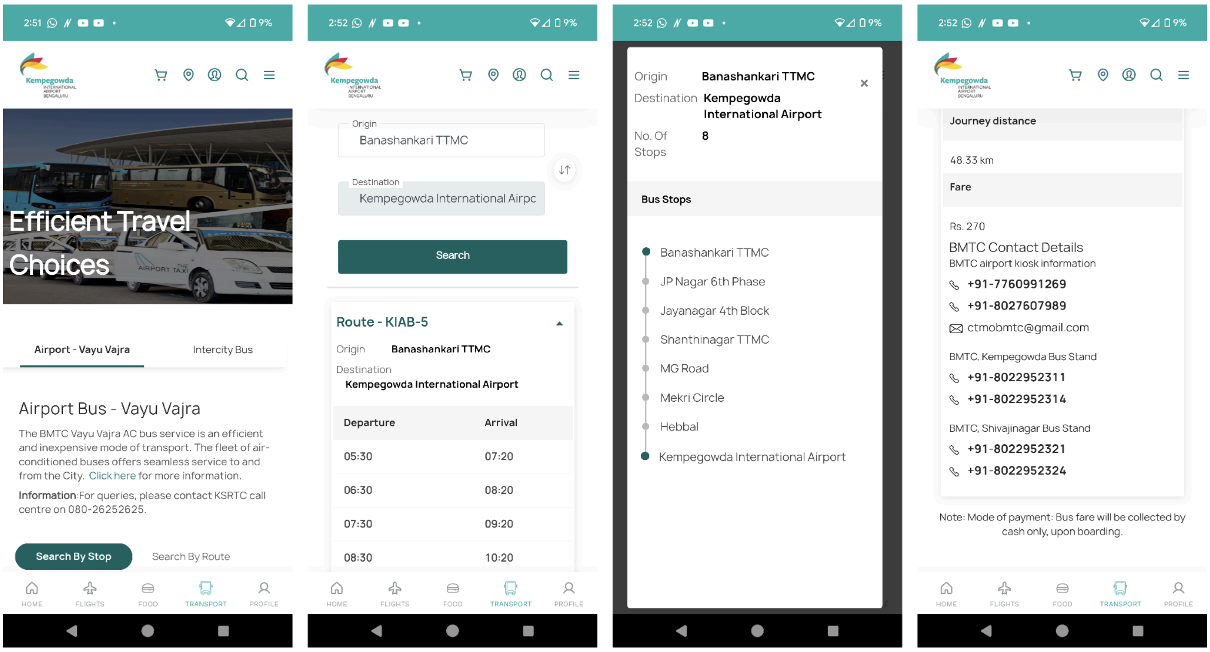
Confirmation bias involves seeking, interpreting, and remembering information that supports existing beliefs, while discounting contradictory evidence. Omission bias refers to perceiving inaction as less morally objectionable than action. Optimism bias leads individuals to overestimate positive outcomes and underestimate negative ones. Additional biases include anchoring bias, where initial information unduly influences judgments, availability bias, which overemphasizes easily accessible information, and overconfidence bias, which results in excessive trust in one's abilities (Tversky & Kahneman, 1974; Das & Teng, 1999). These biases illustrate how cognitive and emotional factors influence decision-making, often leading to systematic errors and departing from rationality.

Design Review: BLR Airport App

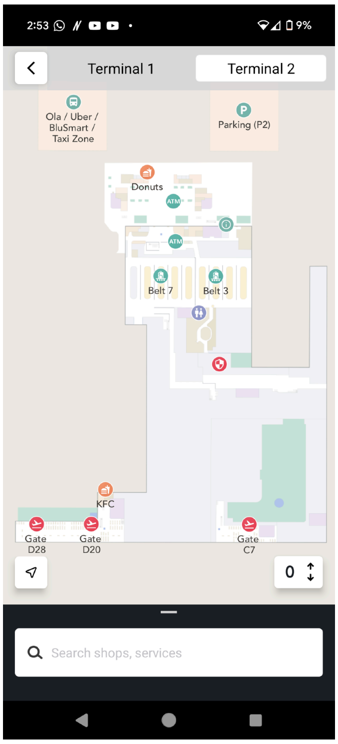
BLR Pulse is an app that provides real-time information about Kempegowda International Airport (BLR) in Bengaluru, India. BLR Pulse provides passengers with a digital travel assistant that helps them navigate the terminal buildings and provides essential information.

The overarching goal of the user here is to catch their flight. The app employs metacognitive principles to guide users throughout their journey starting from reaching their airport to catching their flight and even post landing at their destination (such as the use and found section). First-time travellers (novices) benefit from the following features:

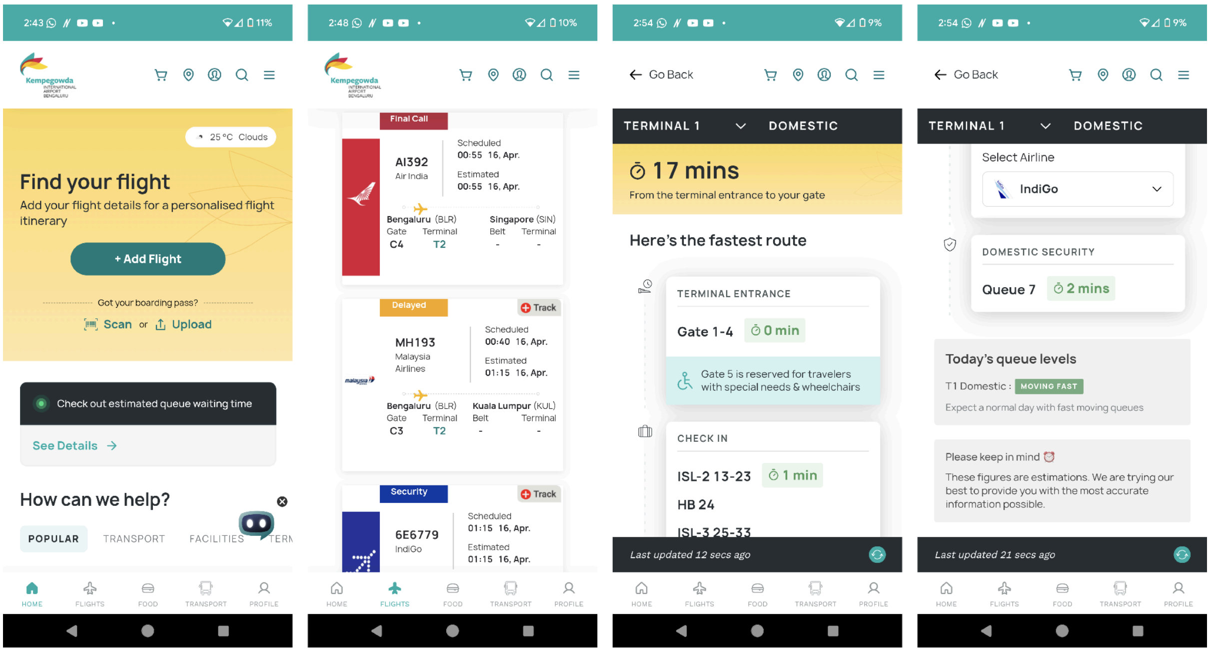
(a) The app shows real-time bus timings and total fare for Vaju Vajra - the airport bus, which goes all over the city - including at what time one would have to be at their local bus stop to catch the bus. Based on the current traffic and the estimated time of arrival, users can decide in advance the mode of transportation they would prefer to take to the airport so that they reach on time. Seasoned travelers (experts) may already have a general idea about the timings and the best mode of transport, but they would still benefit from checking the app once before leaving. (see below)



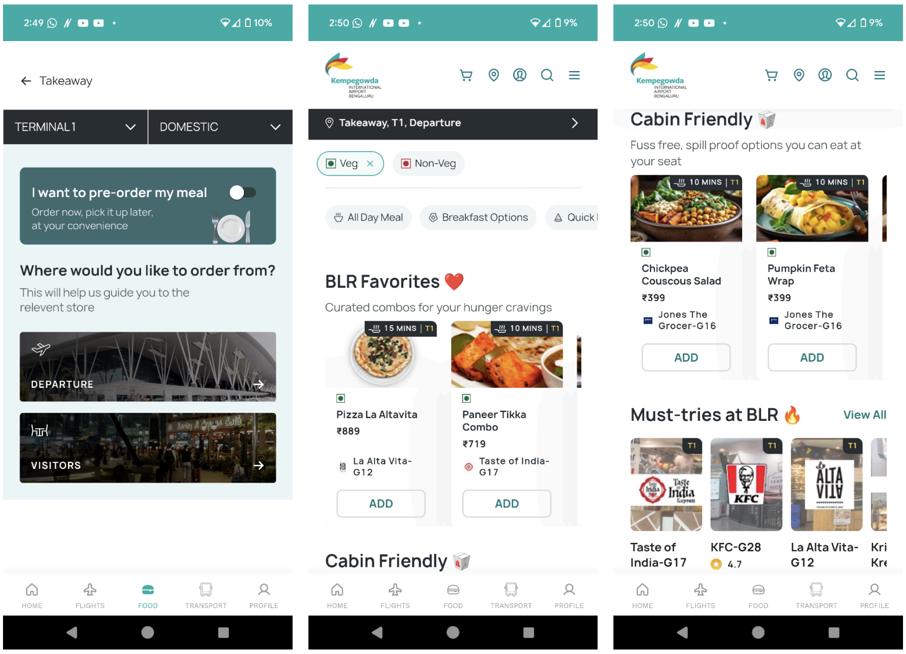
(b) Novices can use the app to track their current location inside the airport and use it to navigate through it. This is an essential feature because large airports are bound to make first-time travelers anxious with the possibility that they may miss their flight if they go in the wrong direction. Frequent fliers from this airport do not require this information.



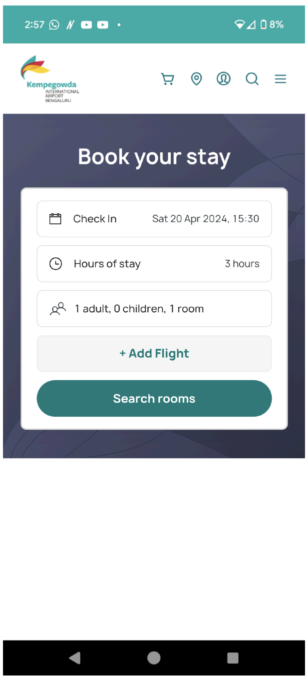
(c) The app shows the status of all flights and at what stage they are at in the onboarding process. If a user enters their boarding pass details, then they can get a personalized itinerary, real-time updates of their flights and gate information. This knowledge is useful for the user to decide how they would like to spend the time leading up to their onboarding. This clear presentation of essential information caters to expert users as well as novices.



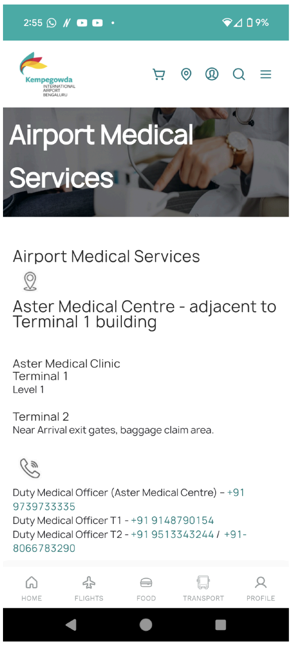
(d) The app allows ordering and pre-ordering meals. It shows each dish with the time it takes to prepare it, its rate and its location in the airport. This follows the utility maximization theory - showing the outcome of what the dish will look like gives the user the option to decide upon a dish that looks best to them. By providing options side by side, the user may also make a decision based on the prospect theory - by comparing the relative gains and losses in the rate of the dish, time it takes to prepare it, and the distance of the restaurant from their current location. This is especially useful to a user since they can decide on a dish that will not make them late for their flight. The app also gently suggests cabin-friendly options - which the user can carry onto their plane without hurrying to finish eating it before boarding. These options help alleviate decision-making fatigue while respecting user autonomy.

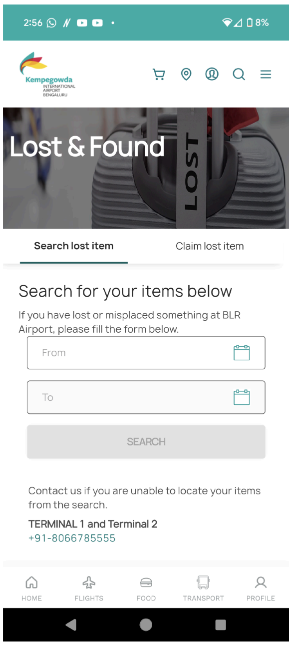


(e) The app allows for metacognitive regulation booking stay within the airport in case of layovers or flight delays.

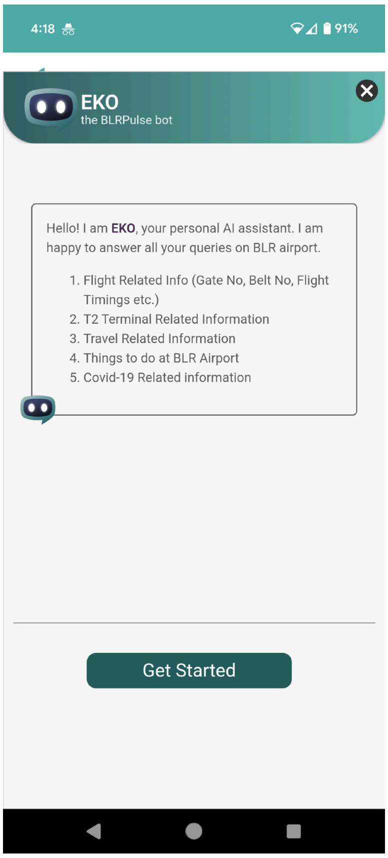


(f) Additionally, the app also offers important information related to the airport medical services and the lost and found section. Users in these situations are bound to experience cognitive overload by getting overwhelmed by a flood of intense emotions. However, with this feature, the app provides a clear strategy and action for a user to adopt without panicking.





(g) The app also includes an AI chatbot called EKO which enhances metacognitive support for novices.



The app can include more features to make it more useful. Experts may benefit from links to airline apps that they can download to view their in-flight meals and entertainment. Presenting a way to track baggage claim carousel from the app would aid in metacognition by enhancing passengers' awareness and understanding of their current situation and task performance. Highlighting current and upcoming events in the city would help those who are landing in the airport to plan their trip; by providing this information, the app can support travelers in setting clear goals and expectations for their trip, allowing them to anticipate and plan for activities they may want to engage in during their visit.

Conclusion

By understanding the neural mechanisms underlying metacognition, recognizing differences between expert and novice metacognitive states, and designing interfaces tailored to these differences, designers can create more effective and user-centered products that enhance decision-making and user experience across various domains. Interplay between metacognition and decision-making is crucial for creating interfaces that support both metacognitive monitoring and decision-making processes. Designers can incorporate features that facilitate self-assessment, goal-setting, and feedback mechanisms to empower users to make informed decisions.

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