Working Memory and Emotion:
Wayfinding in the Edward W. Brooke Courthouse

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Memory occurs in three stages: sensory memory (SM), working memory (WM), and long-term memory (LTM) (Atkinson & Shiffrin, 1968). WM plays a critical role in the memory system, acting as a sticky note for the brain as it holds fleeting, limited information pertinent to present situations (Baddeley, 1983). Broadly speaking, this is central for problem solving, cognitive development, learning, and task completion (Cowan, 2013; Baddeley, 1983). Unlike its LTM counterpart, WM has serious limitations in capacity and time, and is highly volatile (Cowan, 2008). Additionally, WM is strongly influenced by emotions and cognitive load (Sweller et al., 2011). By understanding the underpinnings of WM, experience designers can leverage strategies to create more usable designs that limit the burden on the user (Tracey & Albers, 2006).

WM plays a role in navigation and wayfinding tasks (Fang et al., 2020; Garden et al., 2002; Meilinger et al., 2008). Consider the case of a user attending important court business at the Edward W. Brooke Courthouse, a large multiplex courthouse in downtown Boston. This user must navigate both the built environment and the court system as a self-represented litigant. Attending a court hearing can result in the worst day of someone's life. This is where child custody is decided, evictions are imposed, divorces are finalized, and people are sent to prison. It is no surprise that court users are under an enormous amount of stress and anxiety but are also highly motivated to achieve good outcomes. The stress court users experience can impede their capability to locate their desired destination efficiently (Brown et al., 2020). At the same time, the inability to navigate the built environment can compound the stress of their court appearance, leading to undesirable consequences if they must represent themselves.

Figure 1: Edward W. Courthouse in Downtown Boston (Wikipedia contributors, 2021)

How Working Memory Fits into the Memory System

WM is part of an interconnected memory system. It begins with SM, the basis for bottom-up processing, where stimuli from the environment are picked up by their just noticeable differences through perception (Hecht, 1924; Watson & Robson, 1981). This information forms patterns in the brain automatically to make sense of it (Treisman, 1985). This stimuli representation is held for an incredibly short amount of time, ranging from milliseconds to seconds, acting as a memory trace (Khorsand et al., 2015).

Working memory acts as a shield for sensory information, by employing top-down attention to manage it. It is a temporary bank that briefly stores and manipulates information from both SM and LTM (Baddeley, 2013; Cowan, 2008). This information can be encoded to LTM, through rehearsal (Craik & Watkins, 1973), where it is stored indefinitely in an organized and interconnected system. It can be retrieved based on perceptual cues, recall and relearning (Gazzaniga et al., 2018).

Historically, WM has been seen as a bottleneck to human memory processing. In truth, it behaves this way so that the mind is not overwhelmed. Alan Baddeley describes WM as an air traffic control system “responsible for scheduling and coordinating all incoming and outgoing flights” (Baddeley, 2013).

A Multi-Component Model of Working Memory

The dominant model of WM breaks it down into multiple, isolated components with a central executive at the core. This central executive is aided by other subsystems to free space in WM for it to manage more challenging situations (Baddeley, 1983). This is related to metacognitive knowledge and regulation to stay on track, determine the best strategies and learn from past mistakes (Fernandez-Duque et al., 2000). Baddeley compares this to a busy CEO running a company who must delegate tasks to her employees so she can free herself to more pressing concerns (Baddeley, 2013).

The central executive is supported by the phonological loop subsystem which deals with verbal and written information. It contains two parts: one for storing auditory perception and the other for rehearsing auditory processes. Words that are spoken or read are transferred to this system where they are repeated on a loop to maintain that information to WM. This may have evolved as a language acquisition mechanism. It is limited in its capacity and can only manage one or two auditory tasks at once (Baddeley, 2013). At the Brooke Courthouse, court officers are stationed at the entrance to help direct users to their destination (Note: While I was allowed to take photos of signs at the courthouse, I was not allowed to take photos of people, including court employees). When a user receives these spoken directions, he would commit them to his WM by repeating them over and over to himself. In this way, he memorized his route and can easily navigate to his desired destination.

A second, independent subsystem, the visuospatial sketchpad, manages visual and spatial information. This helps people picture and manipulate objects in their mind as well as orient themselves in the environment. It goes further by showing and controlling visual and spatial information from LTM. Also limited in its capacity, this subsystem will not interfere with the phonological loop (Baddeley, 2013). Navigation and wayfinding are controlled by this subsystem (Garden et al., 2002). The Brooke Courthouse does not contain a map on any directory which would hinder users in navigation. They would not be able to imagine the layout of the space relative to their location and struggle with orienting themselves throughout the building (Fang et al., 2020). A floor plan should be posted at key points on every floor of this building to give people a visual representation of their location relative to their destination.

Though the two subsystems operate independently, they are linked together by the episodic buffer, which also tends to the effects of time. It acts as the buffer to LTM and is responsible for the sequencing of events in LTM (Baddeley, 2000).

Working Memory has a Limited Capacity

The capacity of WM is limited to about four slots of information (Cowan, 2001), though it has been mistaken for 7 +/- 2 (Miller, 1956). Cognitive load contributes to the amount of information that can be held in WM. There are three sources of cognitive load: intrinsic load (the effort related to understanding information), extraneous load (the way information is given) and germane load (the work needed to transfer information to LTM). The buildup of cognitive load on WM processing can lead to errors (Sweller et al., 2011).

One way to illustrate the effects of cognitive load is through wayfinding at the Brooke Courthouse. There is no visible directory in the main lobby of the building. The directory, instead, has low contrast and blends into the background which makes it difficult to perceive. It is located flush against a wall right next to a door leading down a hallway. This grouping makes the user incorrectly assume that the directory is related to what is behind this door rather than containing information regarding the whole building (pre-attentive processing). The way this information is presented increases the extraneous load for the wayfinding activity. Additionally, the design of this directory and printing style makes it unreadable, adding to the intrinsic load. The sign is printed in small letters and is covered by a reflective surface that creates a “seeing double” effect. The load associated with this situation makes wayfinding more difficult to the user which adds to the overall load of having to be at court in the first place (Figure 1).

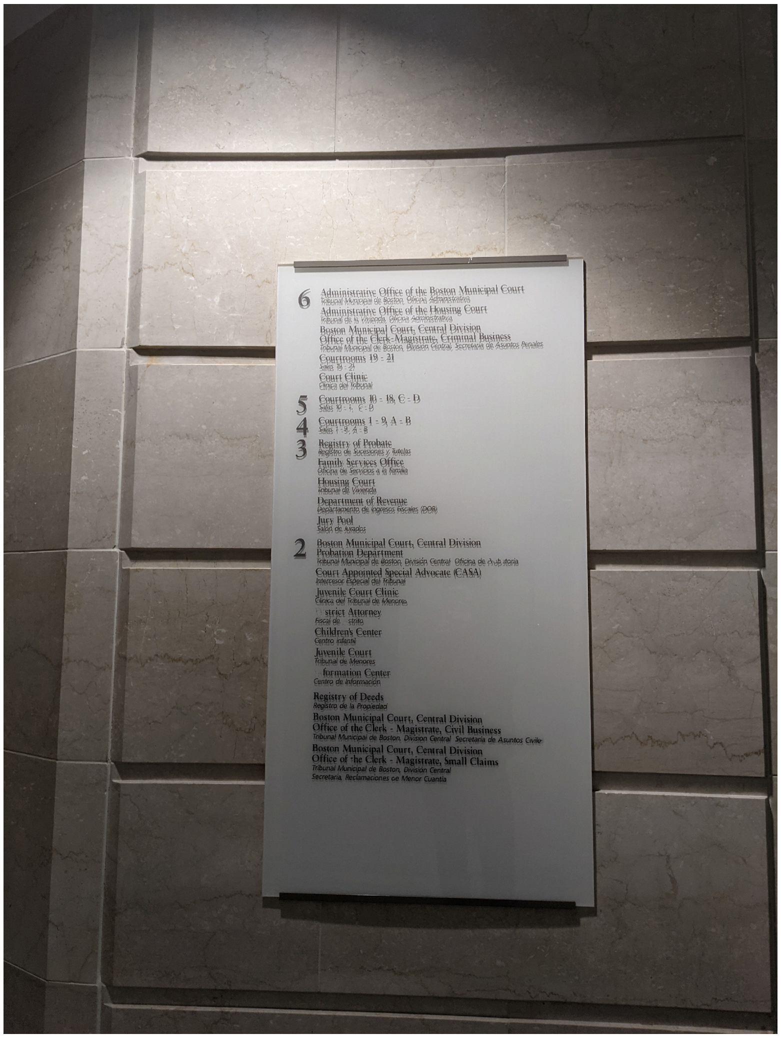

Figure 2 Directory at the Brooke Courthouse. It is placed next to a door (on the left) and is printed in small font. A glass surface reflects light, making it unreadable and creates a "seeing double" effect.

Placing a directory in a central location upon entrance is an expected schema for large spaces such as airports, malls, and hospitals. To improve the user experience, the courthouse must similarly place a directory in the middle of the lobby. It must be clearly marked as a directory, use color to differentiate it from the background, and must be printed in a readable format.

Chunking

Chunking is a strategy humans use to work around the capacity limits of WM. A chunk is a collection of bits of information that occupies one slot in WM. These chunks have a meaningful organization, like schema construction in LTM. These can also be treated as visual chunks based on the proximity of information. Leveraging the associations that already exist in LTM helps with retaining information. Experts can employ strong chunking strategies to make the process more effective. Because of this reduction, rehearsal becomes easier and more efficient as they are transferred to LTM to lighten the load of WM (Craik & Watkins, 1973; Miller, 1956, Thalmann et al., 2019).

To enable chunking, the directory proposed above should also include a map. This would reduce the load of attempting to locate a map separate from the directory and allow users to chunk the two together to create a better association (Florax & Ploetzner, 2010).

Working Memory is Time Limited

Because WM is a temporary storage space, information there is time limited. As soon as attention is shifted to other matters, items in WM suffer from time-related decay. To keep this information top of mind, maintenance rehearsal, a resource demanding endeavor, must be performed. This could be at the expense of other processes currently being managed in WM, which in turn increases cognitive load. A plan needs to be in place to "refresh" the memory and bring those items back to attention (Logie et al., 2021).

A person navigating the Brooke Courthouse would need to keep the route to their destination top of mind. If she shifts her attention away from this activity, there is potential for navigation information to be lost over time. Salient cues must be placed along her route to continually remind her of the location of her destination (Davis et al., 2009). Unfortunately, the Brooke Courthouse does not contain many useful or visible signs to guide the way to her desired destination (see Figure 2, Figure 3, Figure 4, and Figure 5 for examples). Visual cues should be placed strategically to align with the rate of refreshing (7 seconds for 3 chunks and 70 seconds for 1 chunk) (Card et al., 1986). Alternatively, since WM is individual to each person and the rate of decay is difficult to predict based on chunking differences, these signs should be placed at critical decision points, such as the entrance to the building, after exiting stairs or elevators, as directional signs along the route and as perpendicular signs marking doors to offices and departments in the building.

Figure 3: A lack of signs at the Brooke Courthouse. Courtrooms are on the left. Note the low contrast of the sign indicating the courtroom number.

Figure 4: Only one sign at a key decision point at the Brooke Courthouse. This sign is printed on paper and is unreadable.

Figure 5: The low contrast on the sign marking Courtroom 11 at the Brooke Courthouse makes it difficult to read.

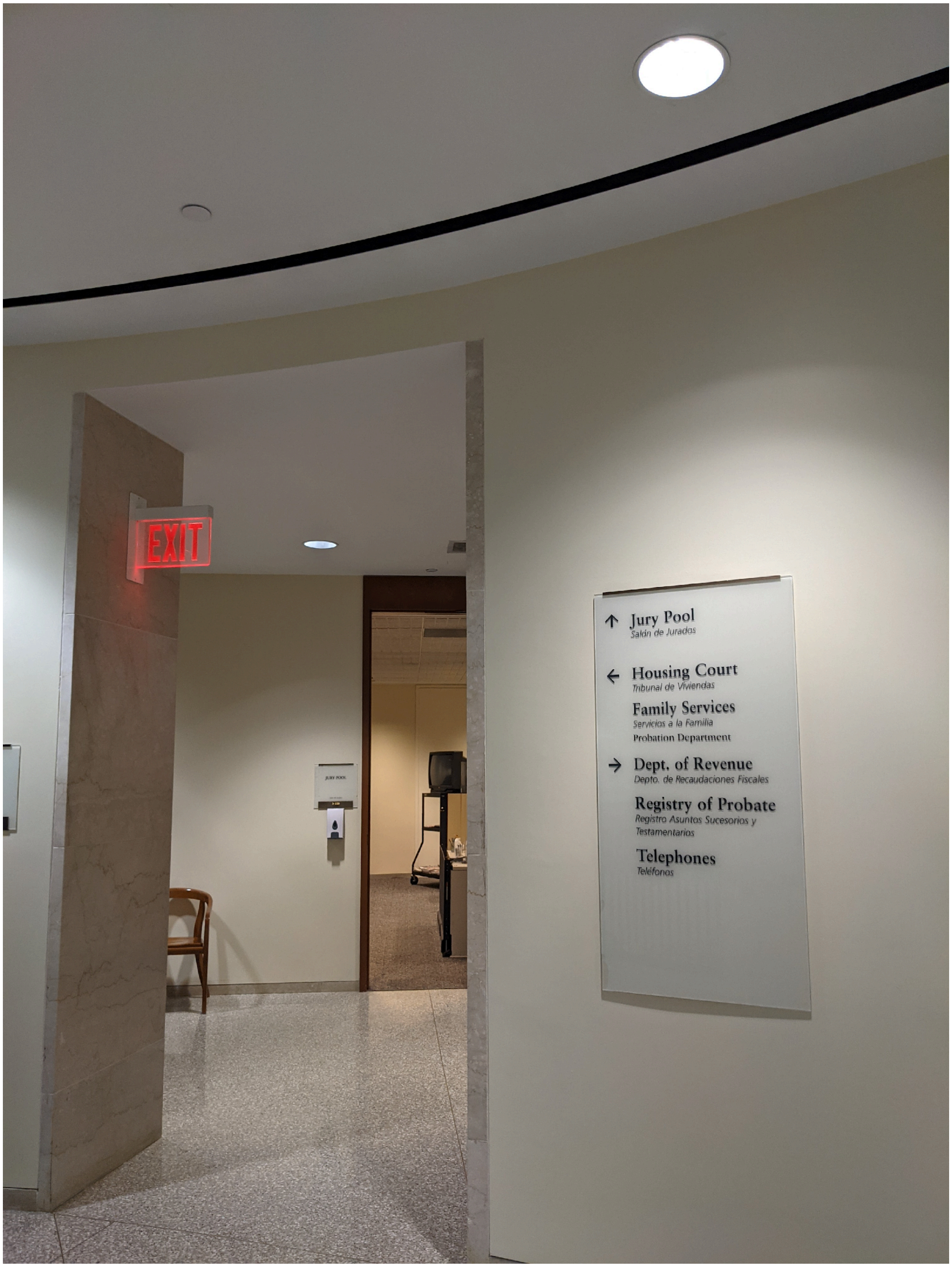

Figure 6: An example of a directional sign at a key location. Note that while the font size is large and clear, the sign blends into the background and has a glass covering, making it difficult to read.

Working Memory is Volatile

Between its limited capacity and its short temporal nature, information in WM is fluid. There are many opportunities for misunderstandings as new information is added from outside stimuli and old information is recalled from LTM. New bits of information are at risk of replacing older ones in WM, which activates competition through interference. Old and irrelevant information may also interfere with new and more relevant information. (Kane & Engle, 2000). This competition for resources is heightened when similar material must be encoded or recalled, resulting in potential for errors, loss of knowledge and confusion (Anderson & Neely, 1996; Banbury et al., 2001). To combat interference, attention must be paid to the most important item in WM to keep it top of mind, while also attempting to inhibit intrusive thoughts (Makovski et al., 2008).

Users appearing in court must focus their full attention to their court hearing. However, distractors such as wayfinding in an unfamiliar environment may interfere with this activity. The court can support these users by including maps of the courthouse layout as well as clear directions to their destination with the summons forms. This would allow users unfamiliar with the building to prepare for their visit by reviewing the indoor layout beforehand (Awh et al., 1998). This would also reduce additional interferences like confusing the layout of the Brooke Courthouse with a different court location previously visited. By doing the upfront work of rehearsal and encoding to LTM, the WM cognitive load is decreased, and more focus can be put into a successful court hearing

The Effects of Emotion on Working Memory

Emotion can have mixed results on working memory, whether in maintenance, load, performance, recall (Lindström & Bohlin, 2011), or interference (Levens & Phelps, 2008). Stress can either improve or impair WM processes. Chronic stress can severely impair WM under multiple load situations. This can lead to missteps, false alarms, slow reaction times (Schoofs et al., 2008), and inappropriate problem-solving strategies (Beilock & DeCaro, 2007). Acute stress, on the other hand, has the potential to improve WM performance. Studies have shown decreased reaction times in these situations, which is an evolutionary advantage to surviving hostile conditions (Duncko et al., 2009). Besides performance, stress can also affect how memories are accessed and encoded for future use, with negative results (Cahill et al., 2003).

While stress exists as a small part of WM and can be helpful, anxiety can completely take over as it resides in WM (Eysenck & Calvo, 1992). Anxiety is an intense, persistent worrying feeling which significantly impairs WM by limiting its capacity, especially in the phonological loop (Darke, 1988; Eysenck & Calvo, 1992), and preventing the transfer of information to LTM (Lee, 1999).

Court users are under considerable stress and anxiety. This can severely inhibit their ability to locate their required destination (Brown et al., 2020). Under these conditions, court users are likely to forget where they need to go, even after being told by a court officer, as their phonological loop is impaired. This situation is frequently observed at the Brooke Courthouse. This can further add to the anxiety of their court appearance and lead to consequences. For these reasons, the Brooke Courthouse must create a wayfinding strategy that includes maps, color coding different departments and the use of symbols and words together to reinforce navigation information by leveraging the visuospatial sketchpad (Florax & Ploetzner, 2010). Currently, the courthouse is not employing any of these tactics.

Motivation pushes people towards completing goals and is closely tied to metacognition. The motivations vary, from loss aversion (Krawczyk & D'Esposito, 2011) to interest, to expertise (Unsworth & McMillan, 2013). Goal oriented behavior is a result of high levels of attention being paid to that activity. Wayfinding in the Brooke Courthouse is no exception. Because the stakes are so high and wayfinding itself is a goal-oriented task, many users are motivated to find their correct location at the correct time. They would pay greater attention to court officer instructions, signs and directories and keep the focus of their goal present in WM. They would also seek out help when lost or confused (Montello, 2005).

Conclusion

Memory is a central process to the human condition, with working memory playing an especially significant role. Once thought of as a constriction due to its capacity and time limitations, WM is now seen as a modulator that maintains a functioning mind. WM is specifically important for wayfinding tasks that contribute to load, stress, anxiety and motivating behaviors. Experience designers must take these into consideration to create navigation systems that are efficient and effective. This is predominantly important while wayfinding in a public institution like the Brooke Courthouse.

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