So basically after reading your document and a few papers:

We live in a dynamic world

Our brains are capable of extracting the statistical structure of the world and generalize past experiences to anticipate future outcomes / use abstract and important features of experiences to generalize to new situations, so we don’t have to entirely learn things anew.   
For example: Knowing to how to make a pizza from scratch, one could abstract important steps and features of the process to make Flammkuchen.

The brain forms cognitive maps of the relationships between landmarks that help an animal navigate their physical environment ([Tolman 1948](javascript:;); [O’Keefe and Nadel 1978](javascript:;); [Burgess et al. 2002](javascript:;); [Ekstrom and Ranganath 2018](javascript:;)). Previous studies have shown that the same organizing principle also applies to other non-spatial types of relational information ([Constantinescu et al. 2016](javascript:;); [Garvert et al. 2017](javascript:;); [Theves et al. 2019](javascript:;), [2020](javascript:;); [Morton et al. 2020](javascript:;); [Viganò et al. 2021](javascript:;); [Garvert et al. 2023](javascript:;)). For example, when participants acquire new knowledge about the relationships between objects by being exposed to experimentally generated object sequences, the hippocampal formation extracts the associated transition structure and stores it as map-like structural representations ([Garvert et al. 2017](javascript:;)).

The representation of both graph structure and semantic relationships in the same system is remarkable, given their very different timescales and modes of acquisition. However, while the two relational structures were represented in the same neural system, they were only partially represented in overlapping voxels. This suggests that the brain extracts separable relational structures in parallel rather than integrating them into one compositional map ([Spiers 2020](javascript:;)). Parallel representations of separable maps likely facilitate generalization and inference in an ever-changing environment where the relevance of stimulus dimensions can shift rapidly.

Both the semantic relationships and transition structures are represented simultaneously but with distinct spatial organization, even when neither structure is task relevant. This enables flexible selection of relevant knowledge in order to guide goal-directed behavior in novel situations. Temporal information is represented in the anterior lateral entorhinal cortex

We are able to do this through an internal world model

The key regions of the brain implicated in this is are the entorhinal cortex and hippocampus.

Tolman coined the term cognitive maps after he saw rats make flexible inferences in mazes , which refers to this internal model of the world that accounts for the relationships between events and predicts the consequences of actions. The work of Harlow also showed that monkeys were able to learn abstract rules/structure of a task, apply these to new task situations and performed better with time.

Hippocampus contains place cells and the entorhinal cortex contain grid cells which have been not only found to represent spatial relationships but also non-spatial relationships such as abstract relations (garvert et al.2017), semantic relations (Zheng et al) social relations and temporal distances

Other key regions include the medial temporal lobe which were also found to represent relevant and irrelevant task relevant graph structures. The mPFC was found to encode representation of a more abstract relational structure independent of the stimulus identities. This representation emerged over time after consolidation (baram et al)

(Missing a gap here to transition into why we investigate temporal hierarchies like in our experiment. Do we know already temporal hierarchies or relationships are represented in the hippocampus or would our study be one of the first to show this?)

To add to the existing body of work, our study which is part of a very large study,

* Investigates if temporal hierarchies are represented in the hippocampus? And does memory consolidation after sleep affect the ability to use representations?
* How are such temporal hierarchies represented along the hippocampal axis?   
  (Could you share a paper that talks about this hippocampal axis and how information could be organized?)
* How does such mapped knowledge play into flexible decision making? Here we are interested in investigating how the prefrontal cortex (the vPFC?mPFC? and OBFC) work in this ensemble. We hypothesize that the OFC could flexibly access and represent model/relational structures.
* Then the mPFC could use this knowledge to compute and update decision variables

Something interesting we could potentially hope to see from the imaging data at some point is if there are anatomical differences where the temporal relationships may be represented depending on the time of acquisition and consolidation.

Another interesting question is how people with different working memory would fair in the task?

An example of learning an abstract set of rules to solve a problem and applying to other situations:   
Lets say i show you a phone number and have you memorize it 017523317389. You dont memorize it as a single string, but rather in chunks. (Chunking) And when you figure this out you can apply this abstract rule of chunking to memorizing other phone numbers. And then this concept can also be applied to other areas such as when you are a musician pianist or guitarist, when you learn large pieces, you play a lot of notes. You dont learn the entire song as a string of notes, you learn them as sections or when you play fast sequences, you still use chunking where you break down notes into triplets or sixteenth notes where you play 4 notes per beat.

**Stuff about the long axis of the hippocampus and functionality  
  
For spatial representations:**

In mice the dorsal hippocampus there are place cells that represent space with smaller place fields. As you move ventrally the size of the place fields increases So dorsal processes more smaller and fine grained spatial information while the ventral part processes more large-scale spatial information.  
In mice, in the entorhinal cortex, the grid spacings and field widths increase from the dorsal to the ventral side.

Evidence in humans also show that this gradient is present where the posterior hippocampus was related to more fine grained representations and more anterior parts were for large-scale spatial information. A similar trend was seen in the posterior part of the entorhinal cortex and anterior part of the entorhinal cortex.

**For non spatial representations like memory in humans :**

A gradient seems to exist in humans in such that in that based off the degree of detail:  
during retrieval of spatial or autobiographical memories, the posterior hippocampus is more activated

Whereas the anterior hippocampus is more involved in gist-like memories or less detailed memories like “i had coffee on Thursday”

**Presentation structure**

We live and navigate in an ever changing complex world filled with places, objects and events.

To help us navigate our brain captures information and organizes them into structured representations that capture relationships between locations, contexts and experiences.

Imagine walking to a cafe in your neighbourhood. You dont individually recall the directions to the cafe, you have a mental map of the streets, landmarks.

We therefore rely on an internal world model which reflects the relationships between events and their temporal dependencies. These models are called cognitive maps.

It is a systematic organization of knoweldege

Such models also allow us to abstract and generalize our past experiences to anticipate future outcomes.

Taking mona’s example, imagine eating at a restaurant and you try out seafood. If you got sick after trying out lobster, you are capable of generalizing this and you might think i may be allergic to seafood and through this you can make better decisions the next time by avoiding seafood.

The idea of cognitive maps was first formalized by Edward Tolman, who showed that rats navigating a maze didn’t simply rely on stimulus-response learning.

Instead they showed highly flexible behaviour like taking shortcuts and adapting to new situations to seek reward when their routes in the maze were blocked.

Later key regions of the brain were identified with the discovery of place cells and grid cells, which gave this theory a biological basis. The discovery of place cells in the hippocampus and grid cells in the entorhinal cortex provided evidence that the brain encodes spatial relationships in a structured representation.

Today the concept of cognitive maps has expanded beyond navigation and evidence shows that hippocampus and entorhinal cortex not only represet spatial relationships, but they also represent non-spatial relationships :

abstract relations (garvert et al.2017)

semantic relations (Zheng et al)

social relations and

temporal distances

Intro to the longitudinal axis of the hippocampus

Studies show that in rodents and humans with regards to spatial processing, there exists a gradient in representations. The more dorsal (rodents) or posterior (humans) parts tend to encode more fine-grained spatial information.

In mice the dorsal hippocampus there are place cells that represent space with smaller place fields. As you move ventrally the size of the place fields increases So dorsal processes more smaller and fine grained spatial information while the ventral part processes more large-scale spatial information.  
In mice, in the entorhinal cortex, the grid spacings and field widths increase from the dorsal to the ventral side.

In terms of spatial information in humans, fMRI studies show that the posterior hippocampus activation increases when encoding or recalling detailed object positions, while increased anterior activation was seen for more broad representations.

And studies look at non-spatial representations such as episodic memories found similar activation patterns. during retrieval of spatial or autobiographical memories, the posterior hippocampus is more activated

Whereas the anterior hippocampus is more involved in gist-like memories or less detailed memories like “i had coffee on Thursday”

Notably, we found an anatomical gradient along the anterior–posterior axis of the hippocampus ([Poppenk et al. 2013](javascript:;); [Strange et al. 2014](javascript:;)), with the graph structure represented in more anterior parts of the hippocampal formation and the semantic map in more posterior parts