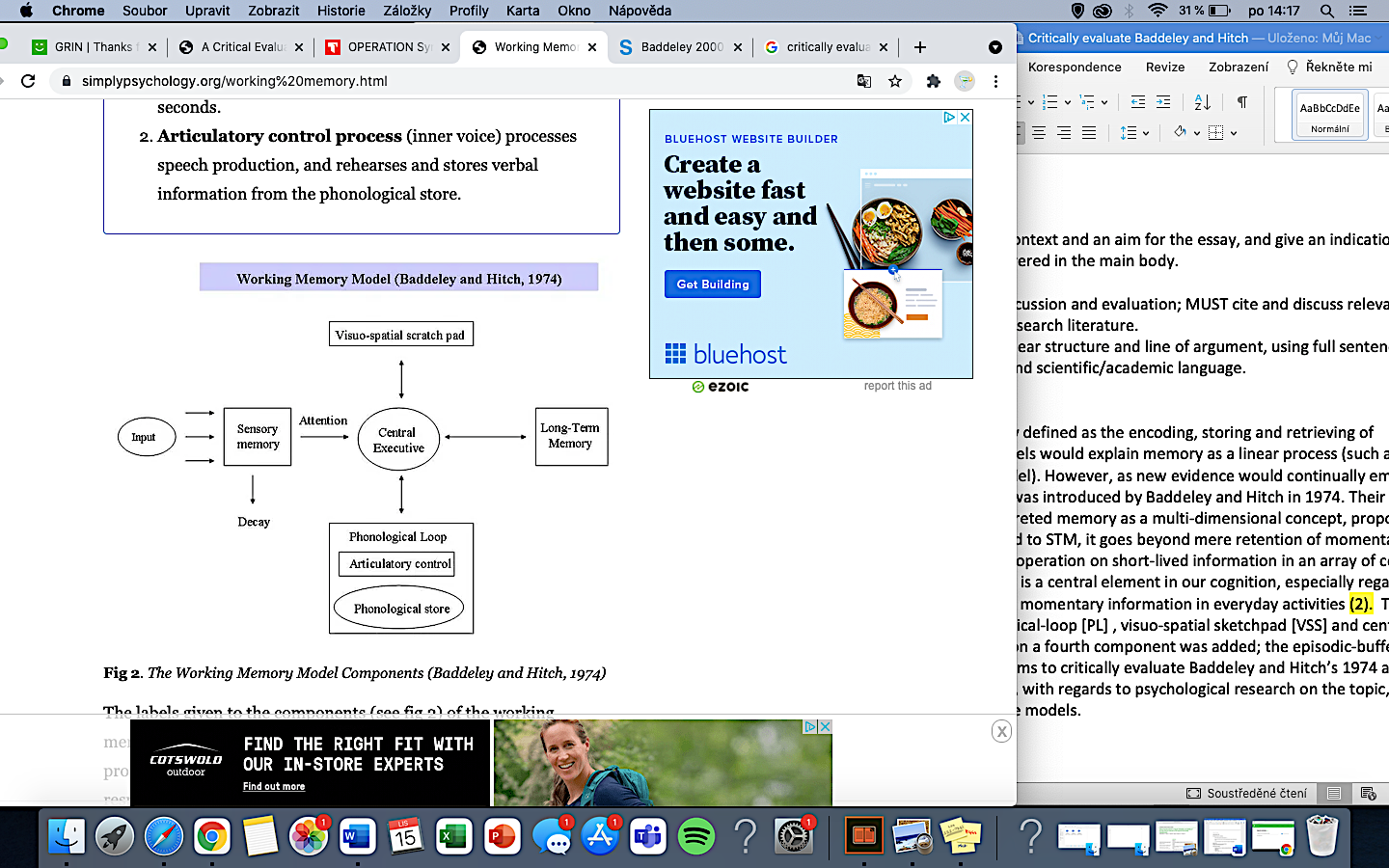
**Introduction**

Memory can be quite concisely defined as the encoding, storing and retrieving of information (Braisby and Gelatly, 2012) and early models would explain memory as a linear process (such as Atkinson & Shiffrin’s 1968 model). However, as new evidence would continually emerge, the concept of ‘working memory’ [WM] was introduced by Baddeley and Hitch in 1974. Their working memory model [WMM] interpreted memory as a multi-dimensional concept, proposing that even though it is closely related to STM, it goes beyond mere retention of momentary information and also supports operation on short-lived information in an array of cognitive tasks. Hence, working memory is a central element in our cognition, especially regarding our ability to process and maintain momentary information in everyday activities (Squire, 2009). The 1974 model consisted of a phonological-loop [PL], visuo-spatial sketchpad [VSS] and central executive [CE], however later on a fourth component was added; the episodic-buffer [EB] (Baddeley, 2000). This paper aims to critically evaluate Baddeley and Hitch’s 1974 and the 2000 working memory models, with regards to psychological research on the topic, and the limitations and strengths of the WMM will be summarized in the conclusion.

**Baddeley and Hitch WMM (1974)**



(Baddeley and Hitch, 1974)

The model proposes that every component of working memory has a limited capacity, and also that the components are relatively independent of each other. Baddeley and Hitch conducted four experiments in 1976 with 92 university students to investigate if a central working memory system is used during verbal reasoning, with regards to the WM being provisionally initially defined in terms of the two main features of STM; having a limited storage capacity and using speech-code information (Baddeley and Hitch, 1976). Experiments 1 and 2 studied the effect of storing additional STM load on sentence verification latencies; as many as six items were correctly recalled with no slowing of verification speed; experiment 3 used a procedure where the STM items had to be verbally articulated during verification, in which the six-item STM loads did slow down verification speed notably, especially for more difficult sentences, and experiment 4 portrayed that latencies also increased by introducing phonemic similarity (words that are phonetically similar) into the verification task (Baddeley and Hitch, 1976). However, the results were inconsistent with the hypothesis of working memory; a limited capacity store was called upon by the verification task, which indicates that instead WM is a general executive system with limited capacity for processing, therefore this suggests that the articulatory system that is used in rehearsal is a ‘peripheral’ of the central executive and actually plays a relatively insignificant role in verbal reasoning.

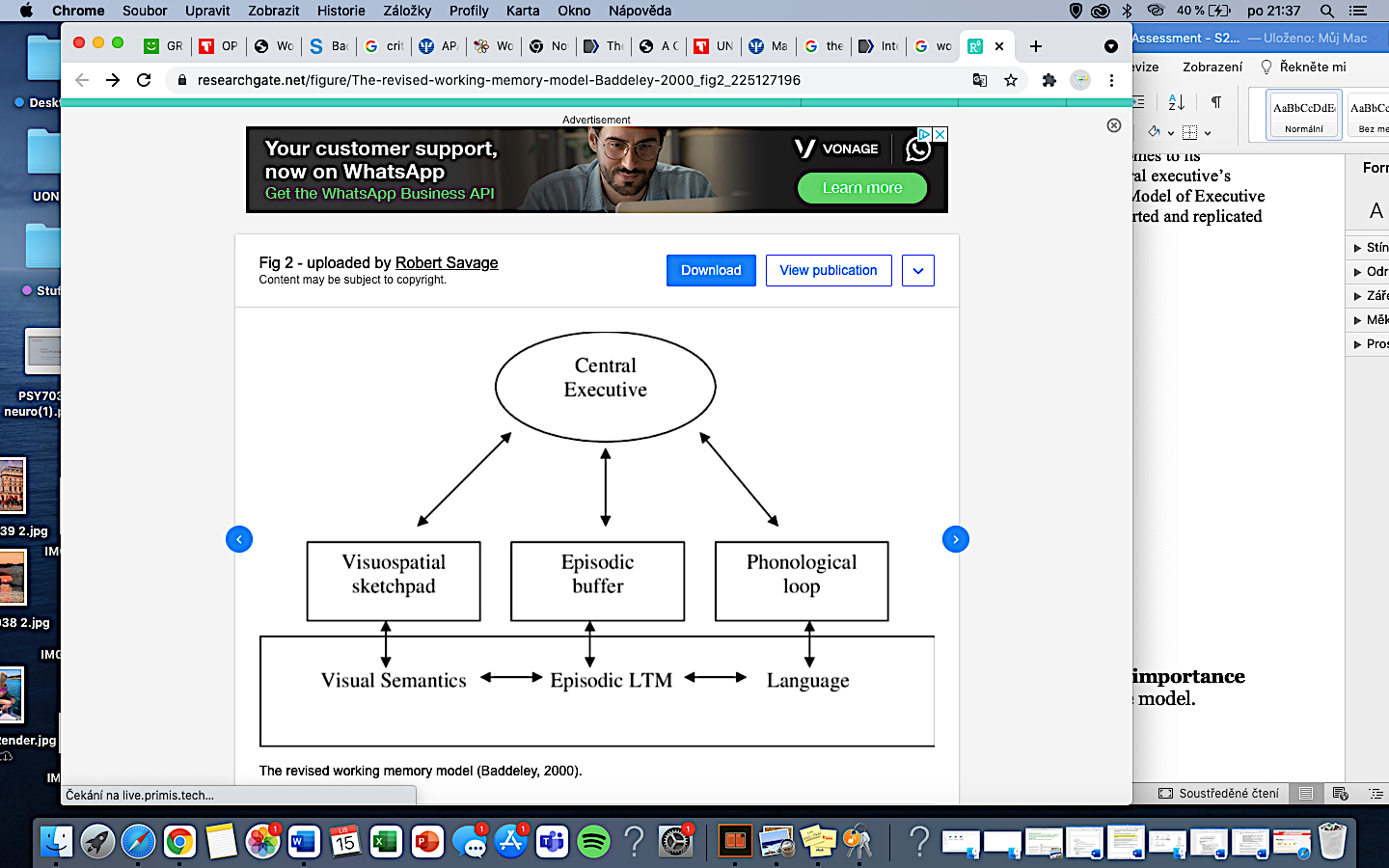
On the other hand, studies such as the ‘KF Case Study’ (Shallice and Warrington, 1974) supports the original WMM. KF was a patient who suffered brain injury which impaired his short-term memory, mainly with regards to verbal information and not the visual information. The case study showed that there are separate components for visual information and for verbal information (phonological loop), as portrayed by the original WMM (McLeod, 2012).

Nonetheless, Liberman, who has investigated how processing within spatial working memory is disrupted by a spatial secondary task (but not significantly by a visual processing secondary task) (Beech, 1984), criticized the visuospatial sketchpad of the WMM. He claimed that even though the WMM suggests that all spatial information was first visual, as they are linked, blind people actually have excellent spatial awareness, even though they are lacking any visual information. Hence, he implied the VSS should have been split into two components; one that is for spatial and one that is for visual information.

With regards to the phonological loop that holds speech based information (Baddeley, 2000), an investigation done by Baddeley, Gathercole, and Papagno (1998) suggested PL serving to acquire new words, like foreign language, but not remembering familiar words (Korbmacher, 2019). In order to portray the PL as an individual component of the WMM, studies have consistently used the phonological similarities effect, which is when the more similar items sound, serial recall accuracy decreases, and the word-length effect, which is when shorter words produce better correct order-recall whilst being independent of word-set size (Korbmacher, 2019). However, current evidence shows that the phonological and semantic processes are both involved in the phonological similarities effect, meaning that the WMM is unspecified in that regard, as well as it is still ambiguous whether articulatory or acoustic similarities govern the phonological similarities effect (Eysenck & Keane, 2015).

The central executive is responsible for the control and coordination of mental operations in the working memory, and includes functions such as supervising the phonological loop and the visuo-spatial sketchpad (Braisby and Gelatly, 2012). When there are problems with the central executive, it causes issues in switching between the different sub-sections of the WMM. Some of the current evidence shows that there are issues with the central executive part of the model, such as Covre et al (2018) found out that the central executive’s limitations were responsible for the decreased performance in multi-tasking instead of limited capacity of other WMM subsystems (Korbmacher, 2019). Their experiment investigated multitasking and the role of the working memory in multitasking by means of the embedded task paradigm, which involved setting up a primary task with a variable task set, which then had to be maintained throughout the performance of a second task with a fixed task before it could be completed (Covre et al, 2019). Their hypothesis was that the capacity to maintain the two task sets avoiding mutual interference would depend on working memory and for their investigation they used the 1974 WMM. In the first part of their experiment, they used an articulatory suppression to examine the potential role of subvocal rehearsal, from which they found out that there was no significant impact on performance, and in the second part they used backward counting (to increase load), from which they found a significant impact on performance even with the simple task of counting backwards (Covre et al, 2019). The tasks and their results portrayed that multitasking is dependent on working memory, as it draws on limited-capacity executive resources but not on the capacity for momentary phonological storage. Even though, there have been numerous investigations on the topic of WMM and the central executive, there is still actually very little direct empirical evidence showing how the central executive work and what are its exact functions, as well as its capacity has never really been measured, due to the difficulty of doing so. Regarding the central executive’s nature, its processes are still not clear in the WMM and again, due to the difficulty of such investigation, researchers are facing problems when it comes to its investigation and task-impurity, making it problematic to identify the central executive’s exact contributions. Hence, the ‘The Switching, Inhibition, and Updating Model of Executive Function’ became a popular alternative, as it is the most empirically supported and replicated factor model of executive function (Jewsbury et al 2016).

**Baddeley and Hitch WMM (2000)**



(Savage et al, 2007)

The original 1974 model was updated by Baddeley and Hitch in 2000, after the previous model has shown numerous failures regarding the explanation the findings of various empirical research. Also, another problem that the model encountered was that it failed to maintain the items whilst reading a series of sentences due to exceeding storage capacity of the phonological look; this can be ‘solved’ by chunking but the absence of any link between working memory and long-term memory in the 1974 model makes this difficult for the multi-component model to explain (Braisby and Gelatly, 2012). Therefore, the ‘episodic buffer’ was added to the WMM, which is a limited capacity multidimensional store that supports the central executive and simultaneously provides a connection to the long-term memory.

This came with assumptions, such as that binding information fed into the central executive from the peripheral short-term stores and from long-term memory to form multidimensional chunks and be able to hold a small number of them at any given time (Braisby and Gelatly, 2012). Research following this assumption tried to investigate whether it is ‘true’ that the processing power of the central executive is necessary for the combination of components into a single representation. For example, Luck and Vogel (1997) showed that people can remember about four multi-featured objects, independently of the number of features in each, consistent with a chunk-based buffer (Braisby and Gelatly, 2012). Another example of supporting research is Rai’s investigation with the aim to understand the role of the episodic buffer of the working memory in inferential reading comprehension (under varying conditions of cognitive load). In experiment 1, there were 67 participants varying in domain knowledge about baseball, that had to read baseball-related stories with or without a current cognitive task load, consecutively answering comprehension questions, and in experiment 2, there were groups varying in English proficiency that read general stories with or without cognitive load and then also answered comprehension questions (Rai, 2014). The findings showed that accuracy and reaction time were contrastingly affected by working memory and the cognitive load and for both experiments, people answered faster under cognitive load conditions (but not at loss of accuracy), which suggests that the episodic buffer is important for different levels of domain knowledge and proficiency, especially with the task becoming difficult (Rai, 2014).

On the other hand, the study of the episodic buffer is still fairly new and is being re-visited in terms of the emergence of novel evidence; the notion of the central executive being needed to ‘feed’ information through the episodic buffer (for feature binding) did not get much strong support, as there is little evidence for the involvement of the central executive in either the binding of simple visual features or in the recall of coherent prose (Gathercole, 2008).

**Conclusion**

The WMM explains much more than the Atkinson and Shiffrin’s (1968) multistore model, and its strengths are that it provides an explanation for parallel processing, unlike the multistore model, and that the KF case study supports WMM’s notion of separate short-term stores managing short-term visual and phonological memories, as well as the model was developed (i.e. 2000 revision of the model) based on empirical evidence from laboratory studies, hence confounding variables were controlled in order to obtain reliable findings. Additionally, contrastingly to the multi-store model, the WMM does not over emphasize the significance of rehearsal for STM retention. On the other hand, it only involves STM, hence It should not be taken as a comprehensive model of memory, and it does not explain changes in processing ability that occur as the result of practice or time (McLeod, 2012). Also, even though it provides more detail of short-term memory than the multi-store mode, WMM has been criticized for its vagueness and simplicity (i.e. unclear about the central executive), as well as even though laboratory experiments are good for reliability, on the other hand they lack ecological validity as the tasks are arguably not representative of real life situations. The 2000 WMM has shown so far that it is highly useful in the explanation of the concept of (working) memory, however it is still fairly new, hence it is definitely open to investigation of the different components, their specific functions and relations to each other, and for more in-depth explanations, and hence perhaps further reconstruction initiated by novel research.

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