Working Memory in Word Recall

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Academic year: 2022/2023

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Master's Thesis

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Zagreb, 2023

Abstract

The goal of this thesis is to determine whether a component of working memory known as the phonological loop and its rehearsal mechanism are naturally employed by participants when performing a free recall task. Before it delves into the specifics of the research, it offers a brief overview of existing working memory research, the phonological loop model and its function. It takes a look at free recall and the effects that often occur in the results of free recall tasks, namely primacy and recency effects, the inverse modality effect, the word length effect, the word duration effect and the word frequency effect. It also examines lexical retrieval as a possible effect of intrusion errors and the kind of intrusion errors that might be expected in the results of a free recall task. The research involved twenty participants, half of whom did the task in English and half in Croatian. The participants were shown two lists of fourteen words each. The English lists contained words with the same number of letters, but each list had words with a different number of syllables. The words in the English lists were of varying degree of frequency. The Croatian lists contained words with the same number of syllables, but one list had words with a smaller number of letters. The words in the Croatian lists were roughly matched for frequency. Participants were divided into four groups (two groups for each language). The first group for each language was shown the words in English and Croatian respectively, one by one for two seconds on a projector screen with a two-second blank screen interval in between words. The second group for each language was first shown the list the previous group had seen as the second list. After they had been shown each list, they were asked to reconstruct it in any order they liked in as much time as they needed. In order to see if any of the participants would choose not to use rehearsal as a strategy at all and to see if being informed would affect overall performance, half of the participants in each group were told in advance what they would be required to do. After they had finished, a brief interview was conducted with each participant to see what methods they used to perform the task. The results showed that most participants used rehearsal in combination with a different strategy, indicating that rehearsal does occur naturally, but that it is not the sole strategy a participant would employ when performing a free recall task. Additionally, the results showed that the primacy effect was not less prominent than the recency effect, as is usual in free recall tasks. The word length and duration effects appeared as expected in the Croatian groups, but the frequency effect cancelled out these effects in the English groups.

Key words: **working memory**, **phonological loop**, **free recall**, **primacy effect**, **recency effect**, **intrusion errors**, **word length effect**, **word duration effect**, **word frequency effect**, **lexical retrieval**, **inverse modality effect**

Sažetak

Cilj je ovog rada utvrditi koriste li ispitanici automatski dio radne memorije poznat kao fonološka petlja i njezin sustav artikulacijskog ponavljanja pri izvođenju zadatka slobodnog dosjećanja. Prije nego što prikaže pojedinosti ovog istraživanja, rad nudi kratak pregled postojećih istraživanja radne memorije, fonološke petlje i njezine funkcije. U radu se istražuje slobodno dosjećanje i učinci koji se često pojavljuju u rezultatima zadataka slobodnog dosjećanja, kao što su efekti primarnosti i recentnosti, obratni učinak modaliteta, učinak duljine riječi, učinak trajanja riječi i učinak učestalosti riječi. Također se ispituje leksičko dohvaćanje kao mogući učinak nametajućih pogrešaka i kakve se nametajuće pogreške mogu očekivati u rezultatima zadatka slobodnog prisjećanja. U istraživanju je sudjelovalo dvadeset sudionika, od kojih je polovica zadatak rješavala na engleskom, a polovica na hrvatskom jeziku. Sudionicima su prikazana dva popisa od po četrnaest riječi. Popisi na engleskom jeziku sadržavali su riječi s istim brojem slova, ali na svakom su se popisu nalazile riječi s različitim brojem slogova. Riječi na engleskim popisima različitih su stupnjeva učestalosti. Popisi na hrvatskom jeziku sadržavali su riječi s istim brojem slogova, ali jedan je popis imao riječi s manjim brojem slova. Riječi na hrvatskim popisima približno su usklađene po učestalosti. Sudionici su podijeljeni u dvije grupe za svaki od jezika te su im riječi prikazane jedna po jedna na projekcijskom platnu u trajanju od dvije sekunde, s praznim zaslonom od dvije sekunde između svake riječi. Drugoj grupi za svaki jezik prvi je prikazan popis koji je prethodnoj grupi bio prikazan kao drugi po redu. Nakon što im je prikazan svaki od popisa, zamoljeni su da ga rekonstruiraju bilo kojim redom bez vremenskog ograničenja. Kako bi se uvidjelo hoće li neki od sudionika odabrati ne koristiti artikulacijsko ponavljanje kao strategiju za izvršenje zadatka i kako bi se uvidjelo kako će informiranost o zadataku utjecati na sveukupan učinak, polovici sudionika u svakoj grupi unaprijed je rečeno što će morati učiniti. Po završetku testa proveden je kratak intervju sa svakim sudionikom kako bi se vidjelo koje su metode koristili za obavljanje zadatka. Rezultati su pokazali da većina sudionika koristi artikulacijsko ponavljanje u kombinaciji s nekom drugom strategijom, što ukazuje na to da do artikulacijskog ponavljanja dolazi automatski, ali da to nije jedina strategija koju bi ispitanik koristio prilikom izvođenja zadatka slobodnog dosjećanja. Usto, rezultati su pokazali da efekt primarnosti nije bio

manje izražen od efekta recentnosti, kao što je uobičajeno u zadacima slobodnog dosjećanja. Učinci duljine i trajanja riječi očekivano su se pojavili u hrvatskim skupinama, ali je učinak frekvencije poništio te učinke u engleskim skupinama.

Ključne riječi: **radna memorija**, **fonološka petlja**, **slobodno dosjećanje**, **efekt primarnosti**, **efekt recentnosti**, **nametajuće pogreške**, **učinak duljine riječi**, **učinak trajanja riječi**, **učinak učestalosti riječi**, **leksičko dohvaćanje**, **obratni učinak modaliteta**

Contents

1 Introduction

Working memory is a term used for "a system that not only temporarily stores information but also manipulates it so as to allow people to perform such complex activities as reasoning, learning and comprehension" (Baddeley, Eysenck and Anderson 2015: 41). It has at times been referred to as "a mental workspace" (Baddeley, Eysenck and Anderson 2015: 42). While there have been many approaches to working memory, all assume that working memory is a temporary workspace necessary for performing complex cognitive activities (Baddeley, Eysenck and Anderson 2015: 42).

Free recall is "a method whereby participants are presented with a sequence of items which they are subsequently required to recall in any order they wish" (Baddeley, Eysenck and Anderson 2015: 49). These items can be numbers, words or pictures.

This thesis examines whether a component of working memory known as the phonological loop and its rehearsal mechanism are naturally used to perform a free recall task. When a participant in a free recall task is given no instruction on how to perform this task, they will naturally employ the rehearsal process, but this be will not be their only strategy. Additionally, this thesis explores some common effects that occur in a free recall task.

Following a presentation of the research procedure, the results are outlined, analyzed and compared among different groups of participants to see if the rehearsal mechanism is the only mechanism naturally employed.

2 Theoretical framework

2.1. Memory

According to Margaret Matlin, memory is "the process of maintaining information over time" (2013: 23) and this process "requires you to continually synthesize and transform information" (2013: 24). According to the Modal Model of Memory, memory consists of three systems: sensory memory (or register), short-term memory (or store) and long-term memory (or store). This model was first introduced by Atkinson and Shiffrin in 1968. The sensory register is where incoming sensory information (also known as a stimulus), most often visual or auditory,

first enters, "resides for a very brief period of time, then decays and is lost" (Atkinson and Shiffrin 1968: 14). For visual registration, the decay rate is several hundred milliseconds (Atkinson and Shiffrin 1968: 16). The short-term store is referred to by Atkinson and Shiffrin as "the subject's working memory" and "it receives selected input from the sensory register and also from long-term store" (1968: 14). Information stays in the short-term store for about 30 seconds, but a limited amount of information can be kept there for as long as one desires using a process called rehearsal (Atkinson and Shiffrin 1968: 14-15). The long-term store is "a fairly permanent repository for information" which is "transferred from the short-term store" (Atkinson and Shiffrin 1968: 15).

2.2. Working memory

Alan Baddeley and Graham Hitch considered the Modal Model of Memory to be too simple and saw at least two problems with the proposition of a unitary short-term storage when it came to long-term learning. The first issue they had was with the Levels of Processing hypothesis proposed by Craik and Lockhart (1972), which suggested that the degree of long-term learning depends on the depth and richness of encoding rather than the length of time information is held in the short-term store (Baddeley 2007: 4). The second problem "was inherent in the neuropsychological evidence" (Baddeley 2007: 4). If the short-term store is crucial in long-term learning, "then patients with a deficit in the STS system should also show impaired LTM performance" and "should be handicapped on many different cognitive tasks", neither of which is the case (Baddeley 2007: 4). Baddeley and Hitch therefore proposed to replace the assumption of a unitary short-term storage with a multimodal system, which they termed working memory in order to emphasize its functional role rather than its storage capacity (Baddeley 2007: 6).

Initially, the working memory model consisted of three components: the central executive, the phonological loop and the visuospatial sketchpad. The central executive is "an attentional control system", while the phonological loop and the visuospatial sketchpad are "subsidiary storage systems" (Baddeley 2007: 7). Upon further study, Baddeley added a fourth component called the episodic buffer to form an interface between the three working memory subsystems and long-term memory (2007: 13). Unlike the other three, this component is "assumed to be accessible through conscious awareness" (Baddeley 2007:13).

2.3. The phonological loop

The phonological loop is a storage system part of the Working Memory Model. Catherine Walter defines it as "a short-term memory mechanism that stores information in phonological form and automatically rehearses that information by unconscious subvocalisation" (2008: 457).
It is "specialised for the temporary maintenance and processing of verbal material" (Baddeley and Gathercole 1993: 260). The phonological loop consists of "a phonological store, which holds information in phonological form, and a rehearsal process, which serves to maintain decaying representations in the phonological store" (Baddeley, Gathercole and Papagno 1998: 158). Spoken language accesses the phonological store directly, but, since the store has very limited capacity and the decay rate for spoken word is very short, a rehearsal mechanism is used "to prevent the verbatim form of words from fading" (Field 2006: 111).

2.3.1. The function of the phonological loop

The function of the phonological loop has been widely questioned and disputed. While there is strong evidence for the existence of such a system, "it is not obvious why the phonological loop should be a feature of human cognition at all" (Baddeley, Gathercole and Papagno 1998: 158). In fact, a large amount of evidence that led to the development of the model of the phonological loop raises questions about its function (Baddeley, Gathercole and Papagno 1998: 158). Many people with phonological memory impairments have few or no problems with everyday cognition, production of speech or language comprehension. However, Baddeley, Gathercole and Papagno proposed that the important function of the phonological loop is related to language acquisition and therefore cannot be "uncovered by experimental studies on adult participants" (1998: 158). "The ability to repeat a string of digits is simply a beneficiary of a more fundamental human capacity to generate a longer lasting representation of a brief and novel speech event – a new word" (Baddeley, Gathercole and Papagno 1998: 158). They proposed that "the function of the phonological loop is to provide temporary storage of *unfamiliar* phonological forms while more permanent memory representations are being constructed" Baddeley, Gathercole and Papagno 1998: 159, emphasis in original). The primary function of the phonological loop, then, is to mediate language learning (Baddeley, Gathercole and Papagno 1998: 159).

Baddeley, Gathercole and Papagno conducted a series of experiments on children and adults with short-term memory disabilities to prove their hypothesis. They started with nonword

repetition, which they deemed "a relatively pure measure of phonological capacity", believing that "owing to the absence of lexical support for these by unfamiliar sound patterns, the child would have to rely very heavily on the representation of the nonword in the phonological loop as means of supporting its repetition" (Baddeley, Gathercole and Papagno 1998: 159). The data they acquired "established a close, natural association between children's phonological loop abilities and their knowledge of native vocabulary" (Baddeley, Gathercole and Papagno 1998: 160).

The next conducted experiment consisted of naming toys by giving two of them familiar names, and two unfamiliar names. Children with low nonword repetition scores had more difficulty with phonologically unfamiliar names than the children with high nonword repetition scores, but there was no reliable difference with the familiar names, suggesting that "new-word learning is indeed linked to phonological memory skills" (Baddeley, Gathercole and Papagno 1998: 160).

Several distinct variables have a known impact on the phonological loop: the word length effect, the phonological similarity effect and the articulatory suppression effect[1] (Baddeley, Gathercole and Papagno 1998: 161). The question Baddeley, Gathercole and Papagno then posed was whether these variables affect phonological learning. They conducted an experiment on native Italian speakers, having them learn pairs of unrelated Italian words and learn Italian-Russian pairs while using articulatory suppression (1998: 162). The suppression had an unfavourable effect on foreign language acquisition, but little effect on paired-associate learning in the native language of the participants (Baddeley, Gathercole and Papagno 1998: 162). This is how they explained it:

> When possible, people use existing language knowledge to mediate their attempts at verbal learning. When unfamiliar phonological forms are presented so that no such knowledge is available to support learning, participants are forced to rely solely on the more fragile phonological loop system to provide the necessary temporary storage of the phonological material while more stable long-term phonological representations are being constructed (1998: 162).

[1] Articulatory suppression is "a technique for disrupting verbal rehearsal by requiring participants to continuously repeat a spoken item" (Baddeley, Eysenck and Anderson 2015: 45). This articulation of irrelevant information prevents the subvocal rehearsal of the verbal input thus affecting the normal functioning of the phonological loop (Injoque-Ricle, Barreyro, Formoso and Jaichenco 2015: 58).

Additionally, they had indeed found that the phonological similarity effect occurs when participants were learning unfamiliar vocabulary from a foreign language, and the phonological similarity effect lead to slower learning (1998: 162). Finally, they found that "word length had no influence on the participants' acquisition of pairs of items in their native language, but it had a substantial effect on the acquisition of unfamiliar Russian vocabulary" (1998: 162). Through these experiments the authors established that "imitation of novel phonological forms may indeed serve to promote the long-term phonological learning of new words, possibly by increasing the period over which they are held in the phonological loop" (Baddeley, Gathercole and Papagno 1998: 163).

Next, Baddeley, Gathercole and Papagno conducted experiments on adults with cognitive deficits. There were "three individuals with severely limited phonological loop function, due in two cases to acquired neurological damage and in the other case to an unidentified developmental deficit" (Baddeley, Gathercole and Papagno 1998: 164). While they exhibited a deficit in learning phonologically unfamiliar verbal material, none of them had poor vocabulary in their native tongue, suggesting that their cognitive and educational advantages outweighed "the limitations set by the slower rate of acquisition of new phonological forms" (Baddeley, Gathercole and Papagno 1998: 164). The conclusion of these experiments was that, in order to establish a direct relationship between verbal short-term memory and natural vocabulary acquisition, it was necessary to study children still in the process of acquiring their first language or adults without exceptional cognitive abilities (Baddeley, Gathercole and Papagno 1998: 164).

After conducting an experiment on a woman with Williams syndrome[2], they established that her "intact phonological memory skills appear to have been sufficient to mediate normal levels of vocabulary learning" (Baddeley, Gathercole and Papagno 1998: 165).

Following that, they studied children with specific language impairment. They found that children with SLI perform poorly on both conventional verbal memory span tests and on tests of nonword repetition when compared with age-matched controls (Baddeley et al. 1998: 165).

[2] Williams syndrome is an abnormal phenotype found in about 1 in 25,000 live births. It is characterized by a typical facial dysmorphology, renal and cardiovascular anomalies together with mild to serious mental retardation and an uneven profile of cognitive-linguistic abilities and deficits. It is commonly held that WS is characterized by spared language in the face of serious deficits in nonverbal tasks such as number, spatial cognition, planning and problem solving. In general, people with WS display a verbal advantage over nonverbal intelligence. This verbal advantage is found in older WS children and adults but is far less marked in the early stages of language acquisition. Although adolescents and adults with WS perform well on some language tasks, they rarely perform at their chronological age level (Karmiloff-Smith, Grant, Berthoud, Davies, Howlin and Udwin 1997: 246-247).

However, once SLI had been resolved, there were no lasting deficits, indicating that weak phonological loop function will delay language development, but not disrupt it entirely (Baddeley, Gathercole and Papagno 1998: 166).

Finally, they conducted experiments on gifted language learners and average language learners. They found that "good phonological memory performance shares a highly specific link with fast and efficient learning of unfamiliar phonological material, but it is independent of nonverbal short-term memory skills and the ability to learn combinations of familiar lexical items" (Baddeley, Gathercole and Papagno 1998: 166).

Based on these findings, the authors put forth the claim that "the primary function of the phonological loop is to provide a mechanism for temporary storage of new words while more stable long-term phonological representations are being constructed" (Baddeley et al. 1998: 166). They have also found evidence of a "relationship between phonological loop function during language acquisition and syntactic as well as vocabulary development" (Baddeley et al. 1998: 167).

Aside from its role in the learning of new words, the phonological loop also plays a role in reading. As Catherine Walter puts it:

> The phonological loop comes into play in a somewhat counterintuitive way in the reading of alphabetic languages. Strange as it may seem, L1 readers of languages with alphabetic writing systems store the most recently read material (about as much as the reader can say in 2 seconds) in their phonological loop rather than in their visuospatial sketchpad. L1 readers of these languages do not mentally see what they have just read: they hear it (2008: 458).

She claims that some of the evidence to support this comes from experiments in which activities which interfere with the phonological loop (e.g. counting out loud) done while reading interfere with understanding what has been read (Walter, 2008: 458).

Additionally, Baddeley, Gathercole and Papagno established that "it is the phonological store that plays a critical role in the learning of the phonological forms of new words" rather than the rehearsal, although it "may be important for maintaining the quality of its representations" (1998: 168).

Overall, the general model of the phonological loop that Baddeley, Gathercole and Papagno propose is that of a highly flexible language learning system where "the primary function of the phonological loop is the processing of novel speech input" (1998: 170). While "participants who are asked to memorize familiar words will make use of the phonological loop", this is its supplementary function and it "evolved for other, more important, purposes" (Baddeley, Gathercole and Papagno 1998: 170).

2.4. Free recall

According to the *Encyclopaedia of Clinical Neuropsychology*, "in the free recall task, a participant is presented with a list of items, typically one item at a time, and then tries to recall the items in any order. The recall period can occur immediately after the presentation of the list (immediate free recall) or after a distraction period (delayed free recall)" (Dudkovic 2018: 1474-1475). The performance of the participant in a free recall task is usually measured by the number of correctly recalled items. There are several factors that affect a participant's performance in this type of task.

> Free recall is influenced by the number of items on the list, the presentation rate of the items, the nature of the items (e.g., words, numbers, pictures), the manner in which the items are processed (e.g., whether participants were given a specific task while studying the items), and the length of the retention interval between presentation of the items and recall. (Dudkovic 2018: 1475).

What frequently occurs in a free recall task are the primacy and recency effects, meaning that the first few items and the last few items on the list are more easily and more frequently recalled by the participants. This is also true for items that are more distinct semantically. When approaching a free recall task, participants are likely to look for "inter-item relationships and use them for organizing their recall" (Bower 2000: 16). There are also appearances of intrusion errors, "reported items that were not on the to-be-recalled list, [which] often include items that are semantically or physically similar to items on the list" (Dudkovic 2018: 1475). Free recall tests are widely used in neuropsychological assessments and are often used to identify patients with mild cognitive impairment (MCI) or Alzheimer's disease (Dudkovic 2018: 1475).

Words are not stored in the mind independently, but rather in close links (Field 2006: 15). This is why mistakes can occur during lexical retrieval. John Field defines lexical retrieval as a way "we reach a word when we need it" (2006: 15). "In lexical retrieval, initiated activity spreads through network, and simultaneously with the activation of the lexical units of the target word, units around the target word are activated as well. In this case, words semantically close to the target word may be activated by mistake" (Salehi, Reisi and Ghasisin 2017: 421). There is also a possibility that a speaker associates a certain sound with the target word (Field 2006: 15).

2.4.1. Primacy and recency effects and the inverse modality effect

Baddeley, Eysenck and Anderson define the primacy effect as "a tendency for the first few items in a sequence to be better recalled than most of the following items", whereas the recency effect is "a tendency for the last few items in a list to be well recalled" (2015: 50). In a free recall task, the primacy effect is "usually much less pronounced than recency, unlike the case of serial recall, when primacy dominates" (Baddeley, Eysenck and Anderson 2015: 50).

Additionally, Maskarinec and Brown claim that "when a subject is asked to free recall a list of unrelated words, the items at the end of the list have a higher probability of recall than items from the beginning and middle of the list" and that "this recency effect is a very well-known feature of immediate free recall" (1974: 328). They believe this is due to there being "no reason for the subject to engage in complex processing of end items to ensure their recall" (Maskarinec and Brown 1974: 329) because the participants discover at the time of testing that they can recall end items first (Maskarinec and Brown 1974: 333).

As defined by Jesse Pazdera and Michael Kahana, the inverse modality effect is an effect in recall tasks "in which silent visual presentation produces better recall than auditory presentation for early or mid-serial items" (2022: 2). According to them, "visual presentation often produces better primacy performance" (2022: 1).

2.4.2. The word length effect, the word duration effect and the word frequency effect

The word length effect is the observation that lists of short words are recalled better than lists of long words (Baddeley, Thomson and Buchanan 1975: 575). The research conducted by Baddeley, Thomson and Buchanan stemmed from the proposition by George Miller in 1956 that "the capacity of short-term memory is constant when measured in terms of number of chunks, a

chunk being a subjectively meaningful unit" (Baddeley, Thomson and Buchanan 1975: 575). This "chunking hypothesis would predict that the capacity of short-term memory, as measured in words, should be constant regardless of the size or duration of the words used" (Baddeley, Thomson and Buchanan 1975: 575). However, Baddeley, Thomson and Buchanan proposed that, given that short-term memory is a speech-based system, its capacity should be measured in phonemes or syllables rather than words (1975: 576). They conducted a series of experiments through which they found that the "temporal duration of the words determines the size of memory span" (Baddeley, Thomson and Buchanan 1975: 578), which is predicted by decay theory (the assumption that forgetting occurs as a function of time [Baddeley, Thomson and Buchanan 1975: 578]) as "less long words than short words can be rehearsed in a given period of time" (Baddeley, Thomson and Buchanan 1975: 578). They found that "the hypothesis that short-term memory capacity is a constant number of items, where the syllable is the item, predicts no word length effect for words matched for syllable number, but differing in spoken duration" (Baddeley, Thomson and Buchanan 1975: 578). Additionally, they concluded that while the word length effect exhibits trace decay, rehearsal may revive a decaying trace and thus the amount recalled will be a function of rehearsal rate (Baddeley, Thomson and Buchanan 1975: 581).

According to Colin MacLeod and Kristina Kampe, the word frequency effect suggests that "the degree of automaticity of processing words decreases as their frequency in the language decreases. Automaticity is a direct function of experience" (1996: 132). Through several experiments on word frequency effect on recall they established that "performance was better on low-frequency words than on high frequency words" (1996: 139). This is somewhat consistent with the findings of Henry Peters, who concluded that "when a series of words, of varying degrees of familiarity, is read once to a group of S[ubjects], the immediate recall records show greater frequency of recall for the words of either extreme of familiarity" (1936: 583-584). However, he also found that "percentage of recall for a list is determined by some factor intrinsic to the list and a factor other than one of familiarity. This intrinsic factor is probably the degree of meaningful connection between the words of the list" (1936: 581).

2.4.3. Intrusion errors in free recall

According to Unsworth, Brewer and Spillers, intrusion errors are "items that were not presented on the current list" and are a common occurrence in recall tasks (2010: 419). These

"intrusions can be broken down into previous-list and extralist intrusions" (Unsworth, Brewer and Spillers 2010: 420). Previous-list intrusions "represent words that were not presented on the current list but were presented on a previous list" while extralist intrusions "represent words not presented on any of the lists but that tend to be phonologically or semantically related to one of the current target words" (Unsworth, Brewer and Spillers 2010: 420). Previous research has shown that about 60% of both types of intrusion occur "at one of the last three output positions" (Unsworth, Brewer and Spillers 2010: 420). Through their experiments, Unsworth, Brewer and Spillers found that "the participants almost always initiated their recall with a correct item" and that "this item tended to be the first item presented" 49% of the time (2010: 422). Overall, they determined that "correct responses were more likely to be generated early in the recall period, whereas errors were more likely to be recalled later in the recall period" (Unsworth, Brewer and Spillers 2010: 423). Additionally, regarding primacy and recency effects, they concluded the following:

> Given that the first item recalled is usually correct, the next item should also be a correct item and should be an item that was presented in close temporal proximity to the previous item. This means that participants should recall the first presented item first, and then recall should proceed in a forward direction, leading to strong primacy and reduced recency (Unsworth, Brewer and Spillers 2010: 427-428).

When an extralist intrusion error occurs, "it is likely an item that shares semantic or phonological features with at least one of the previously recalled items" or "one of the target items on the list" (Unsworth, Brewer and Spillers 2010: 428).

3 Research

3.1. Aim

The primary aim of the research was to showcase that the engagement of the phonological loop and its rehearsal process happens naturally when doing a free recall task. Additionally, the goal of the research was to prove that rehearsal, even when used by conscious choice, is not the sole strategy employed by participants taking part in a free recall task.

Furthermore, more results were obtained regarding the primacy and recency effects, the word length effect and the word frequency effect.

3.2. Participants

The research involved 20 participants. It was conducted on staff members of a Croatian IT company specializing in creating mobile phone games for an international market. The games they create are in English so it is expected of their staff to be fairly fluent in it. The participants were divided into four groups: two who did the task in English and two who did it in Croatian. Half of the participants were informed what the task was going to be in order to see how this would affect their overall recall performance and to see if any of them would choose not to use rehearsal at all.

3.2.1. The English groups

The English Group 1 consisted of five people, three men and two women. The age range of English Group 1 was between 22 and 58 years of age (mean age 40). All of the participants in this group were native Croatian speakers and stated that they use English every day. They took English as a subject in school for between 10 and 14 years (average 12 years). Three of the participants in this group were told in advance what they would be required to do.

The English Group 2 consisted of five people as well, two men and three women. The age range of English Group 2 was between 22 and 36 years of age (mean age 29). All of the participants in this group were native Croatian speakers and stated that they use English every day as well. They took English as a subject in school for between 6 and 11 years (average 7.5 years). Two of the participants in this group were told in advance what they would be required to do.

3.2.2. The Croatian groups

The Croatian Group 1 consisted of five people, two men and three women. The age range of the Croatian Group 1 was between 22 and 27 years of age (mean age 24.5). All of the members of this group were native Croatian speakers. Three of the participants in this group were told in advance what they would be required to do.

The Croatian Group 2 consisted of five people as well, one man and four women. The age range of the Croatian Group 2 was between 24 and 31 years of age (mean age 27.5). All of the

members of this group were native Croatian speakers. Two of the participants in this group were told in advance what they would be required to do.

3.3. Instrument and procedure

The research consisted of showing two sets of fourteen words in English to the two English Groups and two such sets of words in Croatian to the two Croatian groups using an overhead projector in a conference room. Half of the participants in each group were individually told in advance what they would be required to do after seeing the words. The room was well lit. There were no interruptions during any of the showings. Each word was shown for two seconds, with a two second pause in between two words. There was a pause between the two sets to allow the participants to reconstruct the first set of words they were shown. The participants were allowed as much time as they needed for the reconstruction. One group was shown List A first followed by List B, and the other group was first shown List B followed by List A in each respective language.

Before the lists were shown, each participant filled out a short questionnaire (Appendix 2) in which they wrote their age, gender, the number of years they took either Croatian or English as a subject in school and whether Croatian was their native language. After they turned in their lists of recalled words, each participant was interviewed individually on how they reconstructed the lists they were shown. Whether the participants were tired, stressed or otherwise distracted during the task could not be controlled for.

3.3.1. The English lists

The lists for the English group (Appendix 1) were taken from John Field's *Psycholinguistics: A resource book for students* (2006: 113). Each of the fourteen words had seven letters. The words in list A had either one or two syllables, while the words in list B had either three or four syllables. Field stated that the lists had been matched for number of letters and roughly matched for frequency. However, when the results turned out unexpectedly in regards to the primacy and recency effects, the author of this thesis decided to check whether the words were indeed matched for frequency. It was discovered that the words in list A have between 2,384 and 841,137 occurrences in the Corpus of Contemporary American English, while the words in list B have between 2,724 and 596,032 occurrences.

3.3.2. The Croatian lists

The Croatian lists (Appendix 1) were constructed for this research following Field's (2006) example. The words in list A had either two or three syllables. Eleven of them had seven letters, while three words had six letters. The words in list B had either two or three syllables as well. Twelve of the words in list B had six letters and two words had five letters. The words were roughly matched for frequency for each list using the online corpus of the Institute of Croatian Language and Linguistics, with words in list A having between 1,025 and 9,888 occurrences and words in list B having between 80 and 791 occurrences.

3.4. Results

The results of the test are represented for each group separately.

3.4.1. English Group 1

Age	Gender	Knew what the task was in advance	Number of years English taken in school	Number of words correctly reconstructed in the English list shown first (List B)	Number of words correctly reconstructed in the English list shown second (List A)
24	F	No	11	9/14	8/14
27	M	No	12	10/14	11/14
22	F	Yes	14	10/14	10/14
24	M	Yes	13	8/14	9/14
58	M	Yes	10	9/14	10/14
M = 40			M = 12	M = 9.2/14 (65.7%)	M = 9.6/14 (68.6%)

English Group 1 was first shown List B, then List A. They correctly reconstructed 65.7% of words from List B and 68.6% of those from List A, indicating that List A had been slightly easier to reconstruct. There were no words in either list that were not recalled by any of the participants. Two words from List B were reconstructed by all participants from English Group 1 (*caravan*, *economy*), while five words from List A were recorded by all participants (*strange*, *brought*, *sparkle*, *through*, *please*). One word in each list was reconstructed by only one participant – the word *ground* from List A and the word *potato* from List B. The participant who had the best overall average of correctly reconstructed words (21 out of 28) had not been told in advance what

the task was going to be. The informed participants in this group had a slightly worse performance (66.8%) compared to the uninformed participants (67.9%), but the difference is not significant. There seems to be no indication that the number of years the participants took English as a subject in school had an effect on the success rate of the reconstruction.

3.4.2. English Group 2

Age	Gender	Knew what the task was in advance	Number of years English taken in school	Number of words correctly reconstructed in the English list shown first (List A)	Number of words correctly reconstructed in the English list shown second (List B)
22	F	No	11	8/14	6/14
29	M	No	11	3/14	5/14
36	M	No	6	8/14	8/14
28	F	Yes	10	5/14	10/14
31	F	Yes	10	6/14	10/14
M = 29			M = 8.5	M = 6/14 (42.9%)	M = 7.8/14 (55.7%)

English Group 2 was first shown List A, then List B. They correctly reconstructed 55.7% of words from List B and 42.9% of those from List A, indicating that List B had been easier to reconstruct. There were no words in either list that were not reconstructed at all. One word from List B was recorded by all participants from English Group 2 (*caravan*), while there were no words from List A that were recorded by all participants. There were six words in List A that were reconstructed only once (*dressed*, *through*, *glanced*, *squeeze*, *clothes*, *ground*), and there were three such words in List B (*cinema*, *visible*, *educate*). Two participants had the best overall average of correctly reconstructed words (16 out of 28), one of whom had not been told in advance what the task was going to be. The informed participants had a better recall performance (55.4%) than the uninformed participants (45.4%). There seems to be no indication that the number of years the participants took English as a subject in school had an effect on the success rate of reconstruction since the worst performer in this group took English as a subject in school for a larger than average amount of time for this group.

3.4.3. Comparison of English groups

Overall, the average recall performance for List A was 55.7%, while the average recall performance for List B was 60.7%. The word *caravan* was the only word that was recalled by all ten participants across both lists. While List B was seemingly favored by all participants, it may be worth noting that in both groups recall performance was better for the second list shown to each respective group, likely due to the participants being primed for the task by the first list. Statistically, female participants had a better recall performance (62.1%) than male participants (55.3%). The overall recall performance of the participants who were told in advance what would be required of them (62.1%) was better than the recall performance of the participants who were not forewarned (54.3%).

3.4.4. Oral reports – English groups

All five participants who were informed of what the task was going to entail reported using deliberate rehearsal as one of their recall strategies. None of them used it as the only strategy. Other strategies they reported using include visual associations, connecting words into sentences to form a scenario, making pairs of words of opposite meaning, and searching for errors in spelling. All of the informed participants reported using deliberate rehearsal initially, but abandoning it once it broke down. One informed participant reported trying to maintain deliberate rehearsal despite it becoming cumbersome to the extent of the participant being unable to add any new words to the sequence. They eventually had to abandon it as it proved ineffective. Three of the informed participants reported finding the words in List B easier to connect. One of those also reported finding the words in List A more difficult to spell and suspecting this would affect their recall performance. Their recall performance was, in fact, better for List A.

Two of the uninformed participants reported using rehearsal consciously, one of the participants reported using deliberate rehearsal only for the second list (once they were aware they needed to remember the words) while the remaining two participants reported using natural rehearsal (they were aware of it occurring, but they had not actively tried to employ it). Only one of the uninformed participants reported using natural rehearsal as a sole strategy, while others reported using chunking, associative organization and visualization of writing down the words in addition to either natural or deliberate rehearsal. The participant who reported using only natural

rehearsal as their strategy was the worst performer across both English groups. They also reported finding neither list easier to reconstruct.

The participant with the best recall performance for the task in English was uninformed, reported using a combination of rehearsal and chunking, and stated they were not sure whether they were conscious of their rehearsal process.

3.4.5. Croatian Group 1

Age	Gender	Knew what the task was in advance	Number of years Croatian taken in school	Number of words correctly reconstructed in the Croatian list shown first (List B)	Number of words correctly reconstructed in the Croatian list shown second (List A)
26	F	No	12	10/14	12/14
27	F	No	12	10/14	11/14
31	F	No	15	9/14	4/14
24	F	Yes	12	10/14	9/14
27	M	Yes	12	9/14	10/14
M = 27			M = 12.6	M = 9.6/14 (68.6%)	M = 9.2/14 (65.7%)

All of the participants in Croatian Group 1 were native speakers of Croatian. Croatian Group 1 was first shown List B. They correctly reconstructed 68.6% of words from List B, as opposed to 65.7% of those from List A, indicating that List B was easier to reconstruct. Three words from List B were recorded by all participants (*tisuću*, *pčela*, *dvorac*), while only one word from List A was recorded by all participants (*obitelj*). There were no words in List B that were recorded by only one participant, but there was one word in List A that was recorded by only one participant (*gledati*). The participant who had the best overall average of correctly reconstructed words (22 out of 28) had not been told in advance what the task was going to be. The recall performance of the uninformed participants in this group (66.8%) was slightly worse than the recall performance of the informed participants (67.9%).

3.4.6. Croatian Group 2

Age	Gender	Knew what the task was in advance	Number of years Croatian taken in school	Number of words correctly reconstructed in the Croatian list shown first (List A)	Number of words correctly reconstructed in the Croatian list shown second (List B)
22	F	No	12	8/14	9/14
24	M	No	12	9/14	11/14
22	F	Yes	12	9/14	11/14
24	F	Yes	12	8/14	10/14
27	M	Yes	12	8/14	12/14
M = 23.8			M = 12	M = 8.4/14 (60%)	M = 10.6/14 (75.7%)

All of the participants in Croatian Group 2 were native speakers of Croatian. Croatian Group 2 was first shown List A, then List B. They correctly reconstructed 60% of List A and 75.7% of List B, indicating List B was easier to reconstruct. Three words from List B were recorded by all participants (*tisuću*, *pčela*, *maslac*), while two words from List A were recorded by all participants (*obitelj*, *znanost*). There were no words in List B that were recorded by only one participant, but there was one word in List A that was recorded by only one participant (*gledati*) and one word that was not recorded by any participants (*odgovor*). Out of the three participants who had the best overall average of correctly reconstructed words (20 out of 28), two had been told in advance what the task was going to be. The informed participants had a better recall performance (68.9%) than the uninformed participants (66.1%).

3.4.7. Comparison of Croatian groups

The average recall performance for List A was 62.8%, while the average recall performance for List B was 72.1%. There were three words recalled by all ten participants across both lists, one from list A (*obitelj*) and two from List B (*tisuću*, *pčela*). Regardless of which list was shown first, recall performance in both groups was better for List B than for List A. The participants in both groups reported List B being easier to reconstruct due to the words in this list being easier to connect into sentences and create a scenario of some sort. Additionally, List B had

shorter words than List A in terms of the number of letters, although not in terms of the number of syllables. Statistically, there was virtually no difference between the overall recall performance of the male participants (67.9%) and the female participants (67.2%). The overall recall performance of the participants who were told in advance what would be required of them was slightly better (68.6%) than the recall performance of the participants who were not forewarned (66.4%).

3.4.8. Oral reports – Croatian groups

All of the informed five participants reported using deliberate rehearsal and all of them reported this strategy breaking down at some point. None of them used it as their only strategy. Additional strategies they reported using include counting the words, mouthing the words, visual associations and visualisation of writing down the words. One of them reported finding List B easier to reconstruct. The only informed participant who reported using solely a deliberate rehearsal strategy had an average recall performance for their group.

Only one of the uninformed participants reported using deliberate rehearsal. The remaining uninformed participants did not report using any kind of rehearsal, although automatic rehearsal must have been employed. Other strategies the uninformed participants reported using include chunking, looking for spelling errors, and connecting words into sentences to form a scenario. Three of them reported finding List B easier to reconstruct.

The participant with the best recall performance for the task in Croatian was uninformed, reported using a combination of deliberate rehearsal, looking for spelling errors and forming a scenario, and stated they rehearsed sequences of words rather than rehearsing the words one by one.

3.4.9. Intrusion error results

There was a number of errors that occurred in these recall tasks. Despite the fact that the words were displayed visually, the English groups made several spelling mistakes, some of which could simply be slips of the pen (e.g. ‘suqeeze’), while others point towards subvocalisation taking over and the read material being stored in the phonological loop rather than the visuospatial sketchpad, just as Walter suggested (2008: 458). There were four misspelled words in total across both English groups: *ocupy* (two occurrences), *chlotes* (one occurrence), *carovan* (one occurrence), and *suqeeze* (one occurrence). Considering intrusion errors for the English groups,

there were no previous-list intrusions. There were changes in word class of words with a phonological overlap such as *dress* in place of *dressed* (three occurrences) and inflectional changes such as *sparkles* instead of *sparkle* (one occurrence). There were five major extralist intrusions, all of them made by participants in English Group 2. A first output position intrusion occurred when one participant recalled the word *emily,* supposedly instead of the target word *strange*. This is an example of an association based on collocative connection and this mistake was possibly made due to an error during lexical retrieval. Emily the Strange is a fictional character featured in comic books and merchandise. One participant recalled the word *similar*, phonologically related to the target word *cinema*, in addition to both words having the same number of letters and syllables and the intrusion occurring at the same output position where the correct item would be. The remaining intrusions all occurred at the last output position. One participant recalled the word *thought*, phonologically and orthographically related to the target word *through*. Another recalled the word *theatre*, presumably due to its semantic and collocational relation to the target word *musical*, or its semantic relation to the target word *cinema*, both of which this person also recalled. This is an example of lexical retrieval. Finally, a participant recalled the word *suffer*, due to it being phonologically related to the target word *satisfy*, once again an example of lexical retrieval.

There were several intrusion errors in the Croatian groups as well. Just like with the English groups, there were no previous-list intrusions. More inflectional extralist intrusions occurred for Croatian than English, presumably because Croatian is a more inflectional language than English. There were five inflectional intrusions across both Croatian groups: *odgovora* instead of *odgovor*, *spavanje* instead of *spavati*, *znanstveni* instead of *znanost*, *sunčano* instead of *sunčan*, and *krasno* instead of *krasan*. There were six other extralist intrusions, all of them occurring in the later output positions, and almost all of them either phonologically or semantically related to target words. One participant recalled the word *posao*, phonologically related to the target word *poslije*. Another recalled the word *prijatelj*, possibly semantically related to the target word *obitelj*. The only participant who had more than one intrusion error recalled the words *pregled*, phonologically and semantically related to the word *gledati*, and the word *stanovnik*, presumably phonologically related to the word *staviti*. Another participant recalled the word *prestati*, phonologically related to the word *staviti*. Finally, one participant recalled the word *pokret*, which could be an example of lexical retrieval, though the relation to the words from the lists seems to be unclear.

4 Discussion

The results obtained from all four groups participating in this research confirm the hypothesis that the use of a rehearsal process occurs naturally, but that it is not the sole strategy a participant would use when doing a free recall task. Only two out of the twenty participants reported using exclusively a rehearsal strategy, with one of these two reporting using it unconsciously. The participants who reported using rehearsal all reported using it in combination with other strategies. This supports Baddeley, Gathercole and Papagno's findings that the phonological loop will be used by participants in a recall experiment, but memorizing familiar words is not its primary function (1998: 170). All the participants who were informed of what the task was going to be opted to use rehearsal as their primary strategy. This, too, indicates that rehearsal is a strategy that a participant will naturally employ since it was a strategy they all initially used until it broke down. None of them chose not to use rehearsal at all, meaning that the automatic rehearsal process is so ingrained within the working memory model that it was the first strategy they thought of, that whatever strategy they chose to use was initially overtaken by the rehearsal process, or that the participants became aware of the automatic rehearsal process soon after the task began and decided to continue to use it consciously. The overall performance was different within each group. The informed participants who did the task in English had a better performance (62.1%) than the uninformed participants (54.3%), whereas the difference between the performance of the informed participants (66.8%) and the uninformed participants (67.9%) who did the task in Croatian is virtually non-existent. This would suggest that a free recall task is easier to do in one's native language than in a foreign one.

Regarding the primacy and recency effects, the results are mixed. It was expected for the primacy effect to be less pronounced than the recency effect since the recall task was free rather than serial. For English List A, the first four items on the list were recalled by 7 to 9 participants, while the final four items were recalled by 4 to 5 participants, with the exception of the word *please*, which was the third from last word on the list and was recalled by 9 participants. The primacy effect for English List A is therefore more pronounced than the recency effect. However, when it comes to English List B, the first word on the list was recalled by all ten participants, the second word by 7 participants, while the third and fourth items on the list were recalled by 4 participants. The final four items on this list were recalled by 7 to 8 participants, with the exception

of the second to last item, the word *another*, which was recalled by only 3 participants. So the recency effect for English List B is more pronounced than the primacy effect, which was expected since the participants did not need "to engage in complex processing of end items to ensure their recall" (Maskarinec and Brown 1974: 329). It may be worth noting that there are two items in the middle of this list (the words *animal* and *economy*) which were recalled seven and eight times respectively. As for the Croatian groups, the first four items on the Croatian List A were recalled by 7 to 10 participants, whereas the final four items were recalled by only 4 participants, with the exception of the word *milijun*, the third to last item on this list, which was recalled by 8 participants. Again, the primacy effect is more pronounced than the recency effect. Additionally, the word *znanost*, the sixth item on the list, was recalled correctly by 8 participants, with one further participant recalling the adjective derived from this word (*znanstveni*). As for Croatian List B, the first four items were recalled by 8 to 10 participants, while the final four items on this list were recalled by 5 to 6 participants. So the primacy effect is again more pronounced than the recency effect. There were also words from the middle of this list with a high recall rate, the sixth item (*maslac*) and the eighth item (*dvorac*), which were both recalled 9 times. For three out of four lists, the results are inconsistent with Baddley, Eysenck and Anderson's findings (2015), which were based on auditory presentation of items, indicating a presence of an inverse modality effect in this research since "visual presentation often produces better primacy performance" (Pazdera and Kahana 2022: 1).

When it comes to the word length and word duration effects, the research once again turned out mixed results. The overall recall performance for the English lists was better for List B, which had words with more syllables (three or four as opposed to List A's one or two) even though all the words in both English lists had the same number of letters. This is inconsistent with the findings of Baddeley, Thomson and Buchanan (1975). However, the recall performance difference between two lists in English Group 1 favors List A by less than three per cent, and the more significant difference favoring List B in English Group 2 could be explained by the fact that List B was the second list the participants in this group were shown. By then all of the participants were aware of what they would be required to do or, at the very least, that the words on the list needed to be stored. Recall performance for the Croatian groups shows that both groups favored List B, which had shorter words than List A in terms of the number of letters, regardless of whether List B was shown first.

As far as the word frequency effect is concerned, it was expected that low frequency words would be favored if the results were consistent with MacLeod and Kampe's findings (1996), or that recall would be better for "words of either extreme of familiarity" if the results were consistent with the results obtained by Peters (1936: 581). The words in the English lists could not be considered matched for frequency. The two items with the lowest frequency on the English lists were the words *caravan*, recalled by all ten participants, and *sparkle*, recalled by eight participants. The two items with the highest frequency on these lists were the words *another*, recalled by three participants, and *through*, recalled by 4 participants. The fact that these two words are a pronoun and a preposition respectively accounts for their overall high frequency but at the same time demonstrates how function words, unlike lexical ones, are often overlooked when keeping the verbatim form in our working memory for immediate processing. This also seems consistent with MacLeod and Kampe's theory (1996). However, the second and third most frequent items, the words *family* and *economy* for English List B, and the words *please* and *brought* for English List A, were recalled by 8 and 9 participants respectively. The second least frequent word on English List B, *imitate*, was recalled by 7 participants, and the second least frequent word on English List B, *squeeze*, was recalled by 5 participants. These results speak in favor of Peters' proposition (1936). Since the words in the Croatian lists were indeed roughly matched for frequency, they do not yield to this type of analysis. The most recalled items for both Croatian lists are in the middle of their respective frequency spectra.

Most of the intrusion errors for both Croatian and English groups occurred in later output positions and were phonologically or semantically related to target words. Additionally, when the participants started the recall with the beginning of the list, which was done 80% of the time for the English groups, and 60% of the time for the Croatian groups, it was always started with the first item presented. Only one participant started their recall with an incorrect item. This is consistent with the findings of Unsworth, Brewer and Spillers (2010).

Overall recall performance was better for the Croatian groups than the English groups, which might indicate that performing a working memory task is easier in one's native language than in a foreign one.

Age, gender, and the length of time a participant spent taking the language they performed the task in as a subject in school had little or no effect on overall recall performance.

5 Conclusion

The purpose of this thesis and the test conducted for it was to determine that the rehearsal process occurs naturally in a free recall task, but that it is not the sole strategy a participant would employ. Out of twenty participants, only two reported using rehearsal as the only means to reconstruct the lists and their results were either average or below average. The best performers reported using rehearsal in combination with other strategies, namely chunking, looking for spelling errors and forming a scenario. Additionally, both of them were not informed of what the task was going to be. Therefore, this thesis confirmed the hypothesis that when a participant in a free recall task is given no instruction on how to perform this task, they will naturally employ the rehearsal process, but this be will not be their only strategy.

It was expected that the primacy effect in a free recall task would be less prominent than the recency effect, but this did not turn out to be the case, possibly due to the inverse modality effect. The word length and the word duration effects did not occur to the expected degree for the English groups, but did turn out expected results for the Croatian groups. Given that the words in the English lists were not matched for frequency, it is likely that the frequency effect cancelled out the word length and the word duration effects. Intrusion errors took place as expected.

While working memory and the phonological loop do play a role in free recall through storing and rehearsing information, there is an array of factors and a combination of strategies that influences performance on a particular task.

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Appendix 1 – lists

English List A	**English List B**
strange	caravan
brought	imitate
sparkle	cinema
dressed	visible
through	satisfy
station	animal
glanced	economy
squeeze	educate
clothes	holiday
ground	potato
bridge	family
please	occupy
scratch	another
flowers	musical

Croatian List A

obitelj
poslije
spavati
sloboda
četiri
znanost
pristup
nagrada
staviti
sretan
odgovor
milijun
jednako
gledati

Croatian List B

tisuću
unutra
pčela
lupati
krasan
maslac
vreća
dvorac
puhati
sunčan
lomiti
prazan
jabuka
antena

Appendix 2 – questionnaires

English questionnaire

AGE:

GENDER:

NUMBER OF YEARS YOU TOOK ENGLISH AS A SUBJECT DURING YOUR EDUCATION:

IS ENGLISH YOUR NATIVE LANGUAGE?

HOW OFTEN DO YOU USE ENGLISH?

a) every day

b) a few times a week

c) a few times a month

d) a few times a year

e) less than a few times a year

Croatian questionnaire

DOB:

SPOL:

KOLIKO STE GODINA IMALI HRVATSKI JEZIK KAO PREDMET U NASTAVI TIJEKOM SVOG OBRAZOVANJA?

JE LI VAM HRVATSKI MATERINJI JEZIK?