



Concordia Working Papers
in Applied Linguistics

Concordia Working Papers in Applied Linguistics, 6, 2015
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Effects Generated by Cognitive Load Theory: An Experiment with Young Learners' Reading Comprehension Skills

**Pedro Luis Luchini, Gabriela Mariel Ferreiro,
& María Paz González Colalillo**

Universidad Nacional de Mar del Plata

Abstract

Using the Cognitive Load Theory as a theoretical framework, this paper explores the extent to which the redundancy effect influences the L2 reading comprehension skills of a group of young learners at a private school in Mar del Plata, Argentina. A group of 24 Hispanophone English learners participated in this study. They were divided into two groups: A & B. Both groups completed the same reading comprehension task separately, but each used a different mode of presentation. Group A was exposed to a single mode of instruction: *reading alone*, while group B was presented with a dual format which integrated *reading* and *listening*. Both groups had the same amount of time on task. Results revealed that group A (nonredundant group) outperformed group B (redundant group) in the task set. In the light of these findings some pedagogical implications for the teaching of reading comprehension skills in the English language classroom are discussed.

Second language acquisition (henceforth, SLA) requires the building of a knowledge system that can eventually be called on automatically for

speaking and understanding. Although we know that *automatizing* and *restructuring* are central to cognitive theories for SLA, it is still not clear what kinds of structures should be automatized through practice and what should be restructured. Ideas, concepts and words that we know and use automatically may not necessarily be learned through a gradual build-up of automaticity, but they may be based on the interaction of knowledge we already have (cf. Lightbown, Spada & White, 1993). Comprehension is not a simple process of accessing word meanings and then combining them. Indeed, it entails much more than that.

Comprehension involves the construction of a mental representation of a text (e.g. Kintsch, 1998; Zwaan & Radvansky, 1998). This calls for different processes to access word meanings, memory retrieval to elaborate on the text and form connections to prior knowledge, inference to help integrate the current sentence with prior sentences and knowledge (Moss, Schunn, Schneider, McNamara & VanLehn, 2011). Given this complexity, reading comprehension becomes a very important predictor for successful language learning because it involves mental processes of learning, memory and problem solving. Cognitive load theory (henceforth, CLT) is concerned with relationships between working and long-term memory and the effects of those relationships on learning and problem solving (Diao, Chandler & Sweller, 2007). CLT has been used to generate many instructional procedures (Sweller, 2003, 2004) one of which is the *redundancy effect* (henceforth, RE).

The RE happens when the same information is presented to learners simultaneously through different modes of instruction (e.g. spoken and written), requiring them to mentally bring together the multiple forms. This manifold operation generates an extraneous cognitive load that obstructs learning (Chandler & Sweller, 1991; Sweller, 2005; Sweller & Chandler, 1994). When learning to read in a foreign language, learners are often provided with a spoken version of the written text concurrently. Frequently, teachers overtly suggest that both modes of instruction should be provided simultaneously to reinforce learning. Despite the popularity of this practice, support of its effectiveness is highly questioned.

This paper aims to explore the extent to which the RE impinges on a group of young L2 learners' reading comprehension skills, at a private school in Mar del Plata, Argentina, as a result of extraneous cognitive load imposed on their reading process. In the first part of this paper, the theoretical background will be presented. Following, the context, the participants and the instruments for data collection will be described. In the subsequent sections, the results will be presented and the findings will

be discussed. Finally, some avenues for further research in the area will be addressed.

LITERATURE REVIEW

There are a number of interactive variables involved in the process of reading comprehension that have attracted substantial interest over the last decades. When learners read a text they resort to several cognitive procedures to process information which include retrieving and storing new input. To be able to process this information, they need to employ reading strategies to make sense of what they read.

Moss et al. (2011) suggest that the intricacy of reading comprehension processes is the result of individual differences in the strategies that learners employ to understand texts along with what they actually learn from them. Many cognitive processes lie beneath reading comprehension. These processes take root in a number of theories, many of which propose that the reader creates a situation model that comprises a representation of text content (Kintsch, 1988, 1998; McNamara & Magliano, 2009; Zwaan, Langston & Graesser, 1995). Most of these theories propose that readers construct a situational model that draws away the attention from the written form of the sentences that make up the text they create, and incorporates knowledge not enclosed openly in the text. To build up a reasoned situational model, readers need to form a text based on the propositions contained directly in the text itself, and work on this information by using prior knowledge through inference (Brantmeier, 2002; Kintsch, 1988, 1998; Zwaan, 1999; Zwaan & Radvansky, 1998). These multifarious processes frequently involve skimming, scanning, guessing, recognizing word families, reading for meaning, predicting, activating general knowledge, making inferences, and separating main ideas from supporting or secondary ideas (Barnet, 1988).

It is often the case that many language instructors use an explicit dual mode of presenting a text to teach reading comprehension. They believe that presenting their students with both written and spoken texts is more beneficial for reading comprehension to occur. Yet, many studies based on cognitive load theory suggest multiple forms of presenting information turn out to be counterproductive for comprehension purposes (Diao, Chandler & Sweller, 2007). In fact, it has been demonstrated that simultaneous reading and listening is less effective than reading alone. Therefore, anchored in this cognitive theory the current paper sets out to

investigate the effect of simultaneous presentations (read and listen) and single presentations (read alone) on reading comprehension in a foreign language with a group of young learners at a private school in Mar del Plata, Argentina.

Cognitive load theory is an instructional theory generated from the discipline of Cognitive Science, which deals with the mental processes of learning, memory and problem solving. It describes learning structures in terms of an information processing system involving *long term memory*, which effectively stores all of our knowledge and skills on a more-or-less permanent basis, and working memory, which performs the intellectual tasks associated with consciousness (Sweller, 1994; 1999).

Information may only be stocked up in long term memory after first being attended to, and processed by, working memory. Working memory, however, is extremely restricted in both capacity and duration. It is the medium through which we are allowed to think both logically and creatively, to solve problems and to be expressive. Working memory is closely related to *where* and *how* we direct our attention to think about something, or to process information. The biggest restraint of working memory is its capability to deal with no more than about eight elements of information at the same time (Miller, 1956). If the capacity of working memory is surpassed while processing a body of information then some, if not all, of that information may not be recovered. These restrictions may somehow slow down and even impede learning.

Learning consists in the capacity of encoding or storing knowledge and skills into long-term memory in a way that they can be easily recovered and later on applied on demand. This knowledge base is held in a well-structured information network, which is linked to other networks. Networks can be classified into *higher order concepts* and *lower order concepts*, depending on the hierarchical information they contain. These hierarchical information networks are referred to as *schemas*. Schemas integrate detail and complexity as more extensive knowledge is acquired in a content area. Schemas that are well-learnt may be recalled and applied with relative ease. For example, someone learning to surf a wave needs to concentrate keenly on the knowledge and skills required to synchronize some specific movements. After spending some time surfing, however, most surfers are able to do this activity almost mechanically. As mechanization develops, there is a cutback in the need for concentration or a decrease in cognitive load. Worded differently, we may say that when something has been learnt, we mean that this has been successfully

encoded into long-term memory and can later be retrieved when needed (Diao et al. 2007).

As was said earlier, the limited resources of working memory mean that only a few elements of information may be attended to at any given time. New information that is loaded with a high level of element interactivity¹ impinges on learners a cognitive load over and above that imposed by the elements themselves because a need to attend to the relationships between these elements is created. Thus, high element interactive material aggravates the difficulties that result from working memory limitations.

For pedagogical purposes then, it should be borne in mind that the quality of instructional design may affect foreign language reading comprehension instruction and language acquisition in general. That is, if instructional design were given more consideration in terms of the role and limitations of working memory for language acquisition to occur, then better results could be obtained. Since its conception in the early 1980's, cognitive load theory has been used to develop several instructional strategies which have been demonstrated empirically to be superior to those used conventionally (Sweller, 1999). For example, learning in the context of a problem solving situation is facilitated by an intensive use of worked examples rather than an intense use of conventional problem solving. Students presented with worked examples are more likely to dedicate their cognitive resources to identifying and retrieving problem solving structures and applications of rules as demonstrated by the examples. On the other hand, students exposed to conventional problem solving need to engage in search strategies of the problem space to discover for themselves the problem structure and application of the rules (Cooper & Sweller, 1987; Sweller & Cooper, 1985). One example of a search strategy is *trial and error*. However, the most common search strategy is *means-ends analysis*, because it operates by working backwards from the problem aim to the initial information given. This type of activity imposes a relatively high cognitive load, limiting the cognitive resources available for learning (Sweller, 1988).

¹ An activity is considered difficult when there is a need to attend to the relationships *between* the elements that constitute a piece of complex information. These elements interact with each other and, as a result of the high element interactivity, the cognitive load induced goes beyond the resources of working memory.

Cognitive load may be classified into two different types: *intrinsic* and *extrinsic cognitive load*. Intrinsic cognitive load is due exclusively to the intrinsic nature or difficulty of some to-be-learned content. Intrinsic cognitive load cannot be tailored by instructional design. For example, content which is high in element interactivity remains high in element interactivity notwithstanding the way it is presented. On the other hand, extraneous cognitive load is due to the instructional materials used to present information to learners. By altering these instructional materials then the level of extraneous cognitive load may be customized and this, in turn, may facilitate learning. Worded differently, redesigning or engineering instructional materials may reduce the levels of extraneous cognitive load and this may, in turn, enhance learning (Cooper, 1998).

Dexterous instructional designs therefore should be able to manipulate instructional materials and procedures to decrease extraneous or unnecessary cognitive load and, in this way, boost schema construction and automation. Cognitive load theory has been largely used to generate many instructional procedures (Sweller, 2003, 2004). One of these procedures is the *redundancy effect*.

The redundancy effect occurs when the same information is presented to learners in different forms. Presenting information to learners using a dual-format forces them to synchronize the multiple forms psychologically. Having to process multiple forms of the same information inflicts an extraneous cognitive load on learners that hinders learning (Chandler & Sweller, 1991; Sweller, 2005; Sweller & Chandler, 1994). The redundancy effect may occur when spoken and written texts are presented concurrently (Craig, Gholson, & Driscoll, 2002; Kalyuga, Chandler, & Sweller, 2000, 2004; Mayer, Heiser, & Lonn, 2001). The act of having to pay attention to and match spoken and written texts at once slows down learning more than employing one modality only.

In most ESL and EFL reading comprehension lessons, most of the work teachers do implicitly assumes that spoken and written text should be presented jointly when students are learning to read comprehensibly. In cases like this, multiple instructional resources are often encouraged in language teaching to provide learners with rich linguistic knowledge. When the chief aim is to teach learners how to read critically, it is an accepted trend among teachers to provide their students with materials to process that contain multiple modalities such as written text, sound, and video. The belief underlying this common teaching practice is that the more integrative the presentation modes are, the more beneficial for learning they will be.

To sum up, instructional designs that push learners to split their attention between multiple sources of information (for example: read and listen simultaneously) are ineffective for learning to happen. Information should be presented in ways that do not impose heavy extraneous cognitive load (for example: read alone). Therefore, if the main objective is to enhance learners' reading comprehension skills, then only one source of instruction should be used (reading), and the other source (listening), which is redundant, should be removed completely from the instructional materials. In these contexts reading alone would return higher levels of learning than either reading and listening presented in parallel.

METHOD

Context

The experiment was carried out at CADS (Colegio Atlántico del Sur), a private school in Mar del Plata, Argentina. CADS is a private school where students receive a total of 4 weekly hours of instruction and they have their English classes twice a week. They learn English from kindergarten to high school. In high school, all the students are divided into different English language competence levels.

Participants

Twenty-four students in their 1st year of high school participated in the experiment. When the data were collected, they were aged 13. They were enrolled in a low-intermediate course. Their level of English language proficiency was equivalent to that required by the CEFR Level B1 (Common European Framework of Reference for Languages). As part of their English background, these learners were preparing to take the PET Cambridge Exam. To carry out the experiment, the learners were arranged in two groups: Group A and B. Twelve students were selected randomly to participate in each group. There was an even number of male and female participants in each group. Each group completed the same reading task separately and at different times. Both groups had the same amount of time on task. Group A was exposed to a single mode of instruction (reading alone). Group B was asked to read and listen to the same scripted text simultaneously.

Research Instruments For Data Collection

Data were gathered using a full text of about 500 words. This text was drawn from the students' course book PET Result (Baker, 2010). This passage was deliberately selected from this source to guarantee that its linguistic complexity and its length would not become an internal factor that would eventually jeopardize the validity of the study.

After reading/listening to this text (depending on the treatment administered to each group), the students were required to write a summary in which they were asked to include as many ideas as they could remember.

Procedure and Data Analysis

Three evaluators segmented the text into main and secondary ideas. Initially, two evaluators worked together to spot the main ideas. Then, a third intervened to crosscheck their findings. In cases where there were discrepancies between the raters, the three evaluators working jointly discussed them until they reached common consensus. A total of nine main ideas were identified. These ideas were used as "master rating" to analyze the students' summaries and evaluate their productions. So the measure of main ideas in each group was the total number of main ideas divided by 108 main ideas (12 students in each group \times 9 main ideas: "master rating").

The text was fragmented into five different paragraphs, each similar in length (approximately 100 words). These paragraphs were shown to the learners on five successive power point slides. Each slide was held on display for about 30 seconds. Learners were not allowed to control the pacing of the slides. The time allotted for learners to read each slide was calculated taking into account a pilot experience carried out by their teacher, prior to data collection, through which it was possible to measure the average time it took these learners to read and understand excerpts of a similar linguistic complexity and length.

As was said earlier, group A was asked to read the narration on slides, while group B was presented with the audio narration along with a synchronized redundant on-screen text. The slide presentation was shown to both groups individually on two consecutive turns. Right after they completed their reading/listening tasks, the learners were asked to write a summary of what they had read, containing as much information as they could retrieve. They were allowed to write their summaries in L1 or L2 according to their preference to facilitate the expression of their ideas. Figure 1 below illustrates the first slide shown to the learners in which the opening fragment is shown.

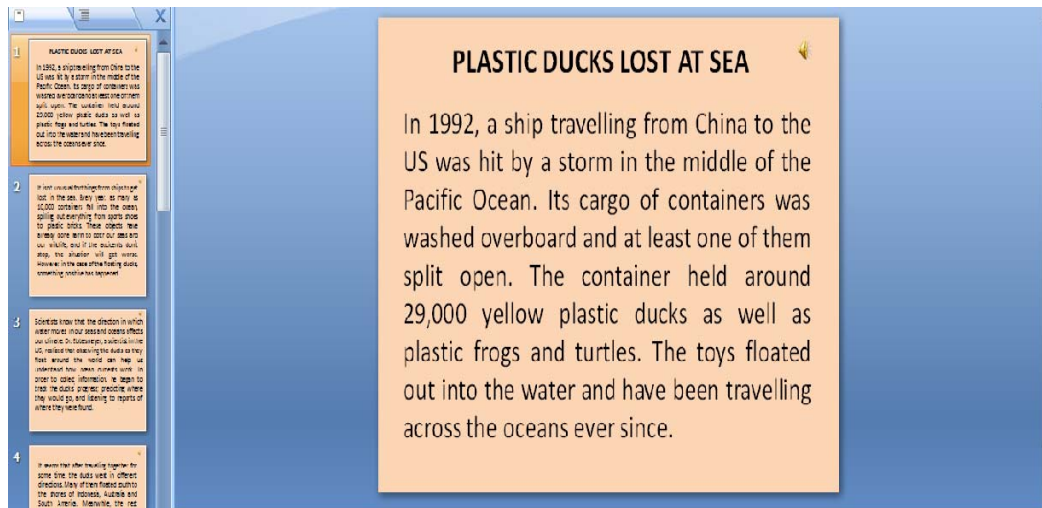


Figure 1. First slide as presented to students

RESULTS

The percentages indicate that there were some interesting differences in the results reported across the two presentation modes. The students exposed to the reading alone treatment identified 51 main ideas out of the total average of 108 gathered per group. The learners presented with the redundant mode of instruction spotted 32 main ideas. Table 1 below shows these results taking into account the number of main ideas identified by each student in both groups.

Table 1. Number of main ideas identified per student and groups

Group A		Group B	
Participants	Main ideas	Participants	Main ideas
Student 1	6	Student 1	6
Student 2	2	Student 2	6
Student 3	6	Student 3	1
Student 4	4	Student 4	5
Student 5	4	Student 5	2
Student 6	4	Student 6	4
Student 7	3	Student 7	0
Student 8	7	Student 8	0
Student 9	6	Student 9	2
Student 10	5	Student 10	1
Student 11	2	Student 11	3
Student 12	2	Student 12	2
TOTAL	51	TOTAL	32

Examination of text comprehension scores indicated that those learners who were exposed to the modality mode (reading alone) obtained better results than those in group B, exposed to the redundant mode of instruction. On applying the ratio suggested, the analysis of means indicates that group A scored 47.22%, while group B achieved 29.62%. That is, on average, the difference between the means reached 17.6%. This difference suggests that group A was able to retrieve more main ideas than group B on the whole. Table 2 below presents the mean score for each group and the difference between the means in percentages:

Table 2. Difference between the means

Groups	Mean scores	Diff. b/ means
A	47.22 %	17.6%
B	29.62 %	

An independent t-test was run to ascertain whether the difference between the two groups' performance scores was significant. The p -value was 0.0305, so it can be said that the difference between these two conditions is significant at the 0.5 level. This result confirms our initial hypothesis in which we claimed that a single mode of instruction decreases the redundancy effect and thus facilitates reading comprehension skills. On the other hand, an instructional design that integrates a dual mode imposes an extraneous cognitive load that manifestly obstructs reading comprehension.

DISCUSSION AND CONCLUSION

The results of this study show that the reading alone mode of instruction is more beneficial for reading comprehension than the dual mode. Group A (nonredundant group) outperformed group B (redundant group). An instructional design that integrates a dual mode of instruction impinges an extraneous cognitive load that affects reading comprehension. This claim often contradicts SLA theories that foster the use of multiple presentations. When the same text is presented using two different modes, learners are pushed to activate two different channels simultaneously in order to process the same information and to build up referential network connections. A set of five different studies were conducted to compare the transfer performance of students who received multimedia explanations consisting of animation and narration (nonredundant group) to the performance of students who received animation, narration, and concurrent on-screen text that was identical to the narration (redundant group) (Mayer, Heiser, & Lonn, 2001, Expt. 1; Mayer, Heiser, & Lonn, 2001, Expt. 2; Moreno & Mayer, 2002a, Expt. 2; Moreno & Mayer, 2002b, Expt. 2a; Moreno & Mayer, 2002b, Expt. 2b). The results for each one of these five experimental tests favored the nonredundant group. These findings are consistent with the results obtained in our experiment.

Decoding an L2 text using one sole mode of instruction already implies a demanding cognitive load on one's working memory. Along these lines, it is very unlikely that L2 learners will have sufficient working memory capacity to be able to handle dual modes of instruction that involve reading and listening simultaneously as this requires a competition of resources in working memory.

Research on CLT provides some sensible answers to manage high intrinsic cognitive load by means of approaches that consider learners' prior knowledge or that allow for the level of relevant load imposed on learners by different instructional materials (Sweller, 1994; 2005). However, some tasks pose more intricate challenges to learners than others because they trigger more high-element interactivity (Sweller, 1988). One of these challenging activities is foreign language reading comprehension because it calls for the construction of complex mental representations (schema) (Moss et al. 2011).

CLT argues that the load directed towards constructing, processing and automating schemas can be manipulated and optimized by means of good instructional design in ways that help learning by directing attention to more relevant learning processes. The findings of the present research show that this outcome was achieved more effectively by one modality mode than with the inclusion of a redundant mode.

PEDAGOGICAL IMPLICATIONS

This study has some practical implications. On the pedagogical side, this study suggests that teachers and material designers should appraise their work in ways that reduces extraneous or unnecessary cognitive load on learners, a fact that will eventually enhance schema construction and automation. These processes, it can be argued, facilitate learning.

A number of steps could be taken in the foreign language reading comprehension class to foster learning. First, teachers should reconsider the impact of the RE on the reading aloud of instructions. It is a standard practice today for many English language teachers to read instructions out loud along with their students. They believe that presenting both reading and listening is like presenting the material twice - giving learners twice as much exposure to the explanation. Another common practice that reinforces the redundancy effect consists in teachers reading out loud a passage along with their students who are later required to explain in their own words what they have understood. In some other cases,

teachers often appoint one student to read aloud a text while the rest of the class does it silently. Once the reading stage is over, one of them is asked to reconstruct what he has understood. Often teachers read out a text along with their students with the intention of assisting comprehension. The RE is also present in some standardized international tests such as the TOEFL exam on its paper-based format. In this test, candidates must read and listen to the instructions in the test booklet. The purpose of this dual mode is to assure that all candidates have fully understood the exam guidelines.

LIMITATIONS

Although the study yielded interesting results, which confirmed our initial hypothesis, there are a number of limitations that call for discussion. To begin with, the number of participants was fairly limited. Had the study included more subjects, the claims presented would have been stronger and more generalizable. More qualitative data emerging from semi-structured interviews or questionnaires would have provided the teacher-researchers with more information coming from different sources about the students' insights into their feelings, perceptions, preferences and opinions about the use of multiple or single mode presentations. Methodological data triangulation involves the use of multiple qualitative and/or quantitative methods. Multiple sources of information can thus be compared to see if similar results are being found. This triangulation process contributes to validate findings. Finally, only three raters analyzed and interpreted the students' productions to identify main ideas and come up with the master rating scale. Inter-rater reliability would have been strengthened if more raters had participated in this evaluation process.

FURHTER RESEARCH

To date, not very many empirical studies have been conducted in English Language Teaching (ELT) mainstream whereby CLT and the RE were explored in the foreign language reading comprehension class. Motivated by the need of obtaining further empirical results to inform teaching practice, similar studies have been recently carried out with groups of

advanced student teachers at UNMDP (Cfr. Tuero, Luchini, & Gomez Laich, 2012a; Tuero, Luchini & Gomez Laich, 2012b). The results of these experiments demonstrated that the redundant mode had a negative effect on these students' reading comprehension skills. These findings confirm, once more, our hypothesis that humans have separate information-processing channels for auditory and visual processing (Mayer, 2010). At present, two other projects are underway. One of them aims at investigating whether text complexity along with dual modes of instruction take a toll on TOEFL students' reading skills (Machado & Luchini, 2013). Using a more qualitative method, the other research work seeks to explore in depth the students' beliefs and preferences when it comes to completing reading tasks using a single and dual mode of instruction (Luchini & Ferreiro, 2014).

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