

## How to Measure the Effects of Open-Plan Intelligibility on Omnichannel Writing Activities?

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**Abstract:** Intelligibility in open-plan office (OPO) affects the cognitive performance of their users since this psychoacoustic characteristic is related to a semantic interference effect because it produces confusion in the comprehension of information. The semantic interference generated by the conflict of attentional resources, increases stimuli perception competition in different attention channels (oral-visual). Semantic interference occurs in an OPO when users distracted by sufficiently intelligible background conversation and affecting performance. However, how to measure the effect of intelligibility on the cognitive performance of written communication activities of OPO users? This study shows the design process for cognitive performance assessment instruments emulating omnichannel writing activities, i.e., the use of simultaneous communication channels, such as recording information during a phone call, composing an email, or chatting. To design the instrument, we first established cognitive evaluation criteria for omnichannel activities. Then, we identified the structure and semantic content of omnichannel activities. Afterward, we quantified the effects of semantic interference based on the semantic coherence and pragmatic cohesion of a text. Finally, we evaluated and selected texts for each type of activity. The results obtained were three instruments to evaluate comprehension of writing processes at different levels of task difficulty, from intelligibility of a word to the detection of errors in a text and the structure of paragraphs. The design of the instrument was based on auditory-visual stimuli like which OPO users are exposed. In addition, applied linguistic readability scales each type of text, considering the characteristics of the persons. This work provides indications for the need for studies focused on specific workplace activities related to cognitive performance in OPO users.

**Keywords:** Cognitive Performance, Semantic Interference, Open-plan Office

## 1. Background

In OPO whose space design features favor communication, however if the intelligibility of the space allows clarity in extraneous conversations this psychoacoustic effect can cause discomfort in workers, which includes the perception of lack of privacy in their workspaces, as well as the feeling of decreased performance (Haapakangas et al., 2018). Particularly, decreased performance as an effect of intelligibility is related to written activities, it should be noted that writing is an essential activity in workplaces to transmit information, from reports and documentation of business processes, as well as to communicate quickly and continuously the day-to-day information (Yadav et al., 2017) (Keus van de Poll et al., 2018) (Yadav & Cabrera, 2019). Background conversations can influence the distraction of OPO workers from their activities, because they lack of perceive privacy are when it is possible to clearly hear one-person conversations, i.e., talking on the phone, or extraneous conversations close to them, which can affect writing a report or an email and even chatting via chat (Marsh et al., 2008). Writing activities are related to different communication channels in the workplace. Because the current trend is to have omnichannel communication, this is due to the evolution of digital communication, which allows simultaneous interaction between calling on phone and writing information highlighted in the call, such as writing an email to answer or report specific events, as well as interaction through instant messaging. Communication needs in workplaces have evolved in such a way that the channels used constantly interact to streamline and maintain real-time information flows (Marsh et al., 2018). The intelligibility of OPO has been related to distracting effects on writing, since it affects concentration and attention of workers, however, these studies have been conducted with general writing activities, using psychometric methods that evaluate attention and possible errors that can be made when writing words, which measures the levels of attention during the execution of the task (Keus van de Poll & Sörqvist, 2016). On the other hand, Smith-Jackson et al., (2016) presented a study that evaluated the socio-technical system of workplaces with an OPO design, in this study the task accuracy was evaluated according to the type of tasks based on the State Change Hypothesis, making a more practical study of how intelligibility can affect writing activities and information search on the web. The effects of intelligibility in writing have been related to location of sound source, number of speakers in background conversations, and the semantic interference produced by background conversations (Braat-Eggen et al., 2019) (Yadav & Cabrera, 2019) (Yadav & Cabrera, 2019). However, the analysis of intelligibility effects on structure should focus on practical activities performed in workplaces with OPO design (Braat-Eggen et al., (2020). For this reason, this study aims to present the design of instruments to assess the cognitive performance of written tasks for omnichannel activities, specifically representing reports of telephone calls, e-mails, and instant messaging conversations.

## 2. Methodology

This article describes a section of a quasi-experimental study assessing cognitive performance in omnichannel activities under the influence of background noise in OPO. Thus, it describes how instruments were developed to measure cognitive performance in specific omnichannel activities, Figure 1. This stage of the study involved the design of the instruments with which the accuracy and latency of writing activities representing writing a phone report, email and chat would be assessed. The design of the instruments began with an analysis to establish the criteria with which the omnichannel activities would be evaluated and then, based on the abilities developed by semantic memory in relation to writing, we defined the structure and semantic content of the texts to contain the instrument. Subsequently, we considered the effects of competing attentional resources causing semantic interference due to the influence of background noise on writing activities. Finally, texts we selected for each writing activity that emulated each of the omnichannel activities, and the validation of these. Initially, a systematic investigation was conducted to review how cognitive performance in writing activities is evaluated in relation to the intelligibility of spaces, finding that the greatest effect is found in the semantic interference produced by background noise, finding different techniques to evaluate the effect on performance. Subsequently, it was necessary to identify the elements of semantic memory since it is related to language and information processing. Semantic memory was used to identify those skills necessary to process information that would serve as a criterion for evaluating cognitive performance in writing. For this purpose, it was necessary to establish the structure and semantic content of oral and written conversation activities for digital communication. During the design of the instruments, specialists aided support the robustness of the data. First, we worked with a speech therapy and speech therapy specialist who provided support for the structure and semantic content of the instruments, we also had the contribution of a speech therapy specialist to establish the content and context of the instruments, and finally, we collaborated with a programmer and a digital designer who helped to emulate the digital content that emulated the omnichannel activities. The expected outcomes were the design of a program to assess cognitive performance with emulators of phone reports, emails, and instant messaging.

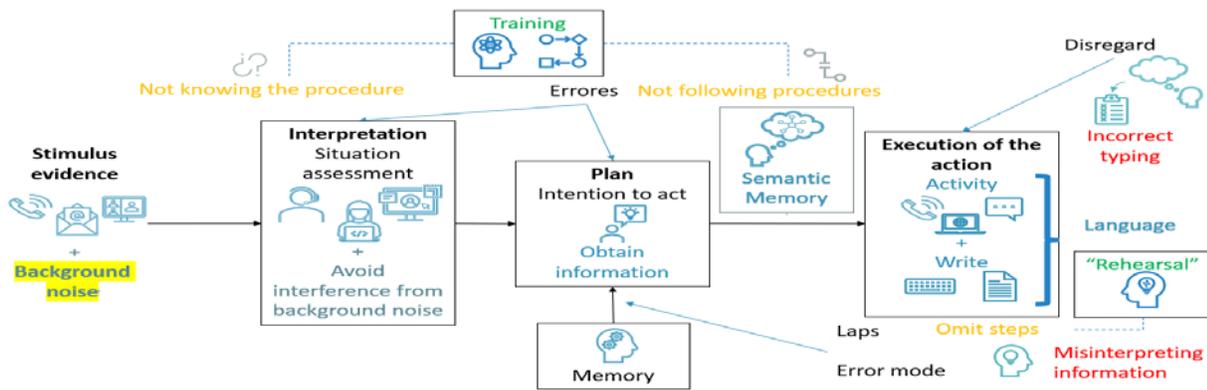


Figure 1. Cognitive Semantic, context of information processing and human error in omnichannel activities

### 3. Results

The design of the work instrument aims to emulate writing in omnichannel activities, the result consists of a by counting the number of correct answers and the execution time in each activity. The following are the steps developed for the design of the 3 elements that make up the instrument. Initially, the assessment criteria were set to emulate omnichannel activities, i.e., the tests will measure the level of cognitive performance for shared activities, especially in the modality of auditory and visual stimuli. The design of the instrument was based on simulating a screen for data recording, in which the words heard would be listed, the objective is to estimate the % of correctly spelled words and time in which the activity was performed, this represents the accuracy and latency of the task respectively; As for written conversation activities, they are related to coherence and cohesion of the text structure, Figure 2.

#### 3.1 Instrument design

The assessment criteria were based on the objectives of each of the instruments: in the case of the telephone call, the aim was to assess listening and language processing skills; with email, the aim was to assess semantic coherence linked to the meaning or thematic axis of the interventions in a conversation; and in the case of chat, the aim was to assess pragmatic coherence linked to the construction of meaning between the interlocutors in a conversation.

Subsequently, the structures and semantic content of the tests were defined based on the level of difficulty of each task. The telephone call was classified as low difficulty since the test consists of detecting the language threshold and correlation with tonal audiometry. For email and chat the test was designed to represent the registration of a textual conversational, but each had increases in the level of difficulty, for email the test consists of the detection of grammatical errors, appropriateness, punctuation, spelling; while for chat the test difficulty reached the highest level with the detection of errors of pragmatic cohesion in a conversation, by means of the syntactic and semantic conclusion of the utterances.

To quantify the effects of semantic interference that could occur in open office users exposed to background noise, the content included different contents embodied in a program to determine the % error for each activity, Figure 2. For the telephone call, the content consisted of lists of phonetically balanced words, which share phonological characteristics, and through a recording of the list of words the participant will write down each of the words heard and with the % of error the level of language processing and listening with background noise will be evaluated.

On the other hand, for email a format was designed that integrates semantic exercises to evaluate grammatical elements of sentences or a text and with the % of error will evaluate the level of semantic coherence and listening with a background noise, but for this test should be considered according to the characteristics of the participants those grammatical elements to be evaluated: spelling, appropriateness, punctuation. For the chat, the test format consisted of semantic exercises to evaluate the syntax and semantics of sentences or paragraphs contemplating the grammatical syntactic function of a sentence (subject-verb-predicate) of a conversation, and with the % of grammatical errors registered by the user, the level of pragmatic coherence will be evaluated.

### 3.2 Instrument validation

Finally, to validate the instruments, as well as for their development, they were classified into three parts. The first part consisted of using methods already used in other studies, so only the activity was adapted to the Spanish language, for which the lists of phonetically balanced words for Mexico were selected. In the second part, the linguistic readability index of a text was used to evaluate the level of comprehension of a text. In addition to the development of the texts we worked with experts in the area, for the evaluation of cognitive performance we contacted a specialist in speech therapy and speech therapy, and to design the instrument in which the exercises will be presented, and the results will be processed we collaborated with a specialist in digital design. Phonetically balanced lists are instruments used to assess language processing, these lists consist of logatomes of the consonant-vowel-consonant form, which are words used to assess intelligibility, that is, how clearly, we hear the words (Hidalgo et al., 2017). These lists have been used to assess cognitive performance and intelligibility among other activities (Hongisto, 2005).

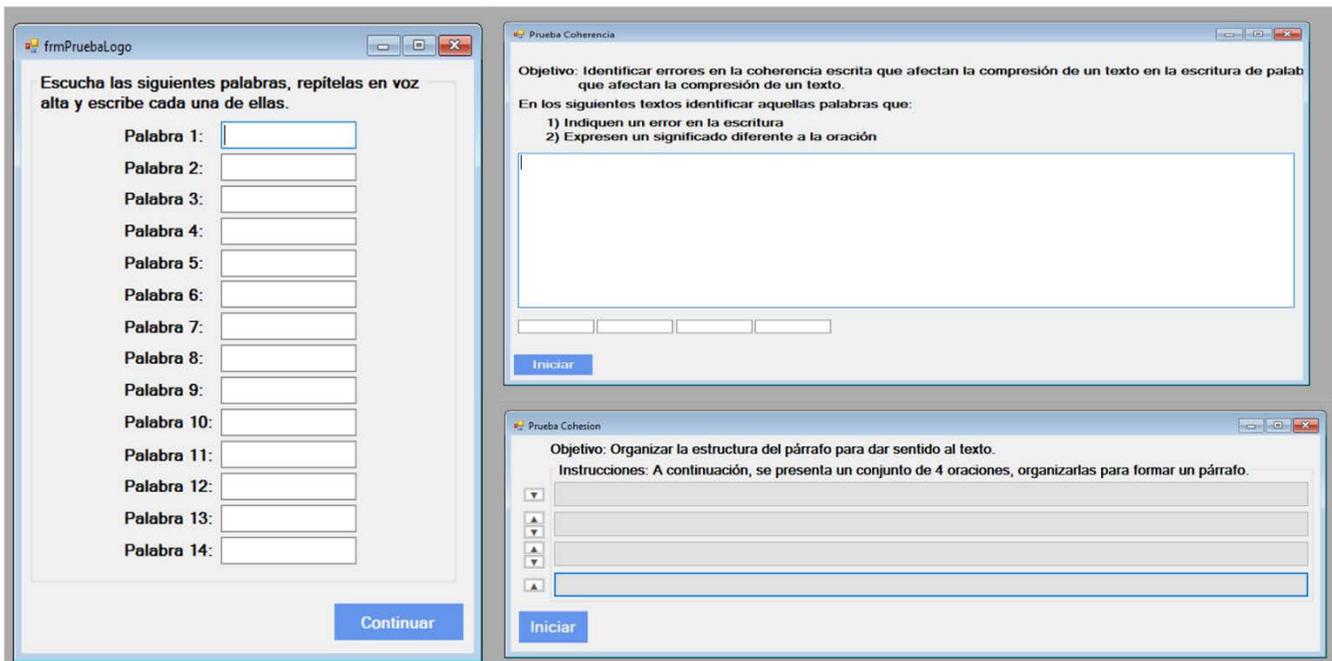


Figure 2. Screenshots of the program designed for each cognitive performance assessment instrument for omnichannel activities.

For the evaluation of the texts, the linguistic readability index was used, which is based on verifying that the content of the written message is contemplated in terms of its clarity and intelligibility by the receivers of the information, which can be attributed to different points: the logical scheme, the syntactic structure, the degree of abstraction, the familiarity of the vocabulary, the size of the words and the length of the sentence (Szigriszt Pazos, 1992).

Of the different existing readability indexes, the one selected to evaluate the texts of these evaluation instruments was the Readability Index  $\mu$  (1) proposed by Muñoz, which has a table for the classification of the index according to the level of difficulty to understand the text, Table 1. Therefore, the texts used in the instrument were selected those paragraphs with a value  $\mu > 71$  to facilitate the understanding of the text by the participants in the study (Muñoz-Baquedano, 2006).

$$\mu = \left( \frac{n}{n-1} \right) \left( \frac{\bar{x}}{\sigma^2} \right) \times 100 \tag{1}$$

Table 1. Readability Scale

$\mu$	Stile	Publication
0 - 30	Very difficult	Scientific - Philosophical
31 - 50	Difficult	Pedagogical - Technical
51 - 60	Bit difficult	Literature - Popularization
61 - 70	Adequate	Media
71 - 80	Not easy	Novel - Magazine
81 - 90	Easy	Newsstand Magazine
91 - 100	Very easy	Comics - Cartoons

#### 4. Conclusions

In this study, the design of the cognitive performance assessment instruments was considered different semantic components for the execution of writing activities. Background noise has been related to effects on writing, Seddigh et al., (2015) indicated that workload should be studied by type of activity to identify how they were affected by background noise. While Keus van de Poll & Sörqvist, (2016) also suggested that it was necessary to assess quantitative aspects of writing and qualitative aspects for written texts. According to these lines of research the cognitive performance assessment instruments for writing established as quantitative aspects the accuracy and latency of the task, regarding the quantitative aspects the level of task difficulty was based on omnichannel activities for the use of more realistic and common tasks in any workplace. According to previous studies have used different psychometric tests to evaluate the cognitive performance of users of open offices exposed to background noise, however, these tests only contemplate attention and memory skills (Mama et al., 2018), which does not allow evaluating a more complex level of workplace activities. On the other hand, the study of Smith-Jackson et al., (2016) gave rise to emulate office activities which allow evaluating the effects of physical-environmental conditions on workers, Braat-Eggen et al., (2019) on the other hand recommends conducting research linked to realistic complex tasks for real acoustic sound environments. Therefore, based on these aspects, the development of this study sought to develop specific instruments to assess cognitive performance for omnichannel activities, which will allow evaluating semantic skills that may be affected by background noise. The development of these instruments implies an advance in linguistics to assess cognitive performance and to be able to represent more realistic scenarios in experimental designs for tests with writing applied in their activities by open office workers, which can be affected by background noise. The contribution of this study is the contribution to the evaluation of cognitive performance with linguistic instruments, in this case specific to the Spanish language. In addition, the instrument provides an approach to the evaluation of the effects of semantic interference in written activities for field studies that can be evaluated under different environmental conditions.

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