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Working Memory, Executive Functions, and Emotional Intelligence in Second Language Writing

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Abstract

The current study employed an audiovisual blended-emotion stimulus to explore whether particular aspects of working memory and trait emotional intelligence (TEI) are significant determinants of linguistic complexity, accuracy, and fluency in second language (L2) writing. Fifty-nine L2 learners of Spanish completed a visuospatial working memory task, four executive functioning tasks assessing inhibition, shifting, and updating abilities, a self-reported measure of TEI, and a writing task based on an animated short film that required participants to describe the plot of the film and express how they felt about it. Classical and Bayesian statistical methods were used to analyse the data. Updating ability proved to be the best variable to predict both subordination density and linguistic accuracy in L2 writing. Individual differences in controlled search and retrieval processes seem to account for these results. On the other hand, TEI was not linked to any of the L2 writing performance measures but did correlate negatively with updating ability. Furthermore, a trade-off was observed between fluency and lexical complexity, suggesting that paying attention to lexical choices to convey (emotional) meaning might slow down production speed.

Keywords: inhibition, shifting, updating, executive functions, emotional intelligence, emotional discourse

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Introduction

Writing is a challenging task for both first language (L1) and second language (L2) users. Retrieval and processing of information, attention, memory, decision making, language, and motor execution are all parts of the writing process (Brand, 1987; Kellogg, 1996). Writing is also a creative activity as individuals have to produce novel content by combining words and linguistic patterns to express ideas, opinions, and emotions based on their own perspectives and those of others (Zhao, 2015). Thus, as Brand (1987) pointed out, "a realistic and complete psychology of writing must include affective as well as cognitive phenomena" (p. 436).

Despite the bulk of research on the factors that influence writing processes and products, the role of working memory —and particularly of its executive functions— has received little consideration in L2 writing studies (Kormos, 2012; Mavrou, 2017), and empirical evidence to date has yielded mixed results. Important caveats also exist about the interaction between working memory and other affective or emotion-related variables, which also intervene in the act of writing. In this regard, D'Mello and Mills (2014) made the following remark:

> As is typical in the field of education, most of the efforts to increase writing proficiency have focused on the cognitive aspects of writing, while ignoring the emotional ones (Schutz and Pekrum 2007) … Insights gleaned from a research program that focuses on the emotions that arise during writing and how they influence writing outcomes is a first step towards developing interventions that promote writing proficiency in a manner that coordinates cognitive and affective processes. (pp. 141–142)

Building on the premise that cognition and emotion must be seen as

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interconnected and interdependent concepts (Pessoa, 2008, 2009; Phelps, 2006), the current study set out to explore the joint effect of specific functions of working memory (visuospatial working memory capacity, inhibition, shifting, updating) and trait emotional intelligence on the creation of linguistically complex, accurate, and fluent L2 written texts which were prompted by an audiovisual blended-emotion stimulus.

Working memory

Over the years, working memory (WM) has become a key construct in cognitive science and in most —if not all— theories and models developed to explain human cognition. Different WM models emphasise different aspects of this construct (see Miyake & Shah, 1999, for a comprehensive overview). For instance, Baddeley's prominent model comprises four components: (1) the phonological loop, a temporary storage of memory traces that rapidly decay unless they are refreshed by the subvocal rehearsal system; (2) the visuospatial sketchpad, which enables the processing, retention, and integration of spatial, visual, and probably kinaesthetic and haptic information; (3) the central executive, a domain-general mechanism responsible for attentional control, attention switching, and the inhibition of interference; and (4) the episodic buffer, which provides a multimodal storage for binding information from the subsidiary systems with prior knowledge stored in long-term memory (see Baddeley, 2012, for a recent account of this model).

From an individual differences perspective, Engle, Kane, and Tuholski (1999; Kane, Conway, Hambrick, & Engle, 2007) conceptualised WM as a system comprising long-term memory traces active above threshold, processes that maintain this activation, and controlled attention. Controlled attention is involved in the rehearsal and processing

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of information, the retrieval of displaced items from the focus of WM, and the inhibition of irrelevant representations in the face of interference or distraction. A more recent theoretical framework proposed by Unsworth and Engle (2007b) made the distinction between primary and secondary memory, concepts that had been originally introduced by James (1890). Primary memory maintains active mental representations for ongoing processing, which are displaced to secondary memory by either incoming information or attention disengagement but could always be retrieved through the selection and use of appropriate cues.

Drawing on these and other WM models that cannot be described here in detail, WM can be defined as a mechanism comprised of both domain-general and domain-specific mechanisms that are necessary for the active maintenance and processing of information. Domain-specific mechanisms are responsible for strategy implementation such as chunking, association, and articulatory rehearsal. Domain-general mechanisms, also known as executive functions, encompass a wide range of abilities that enable individuals to update memory traces, monitor and coordinate the steps or elements required to execute a concrete plan, action, or mental activity, inhibit cognitive interference, distractions, and prepotent responses, and switch accurately and flexibly between different tasks and mental processes (Jonides & Smith, 1997; Miyake & Friedman, 2012; Miyake et al., 2000; Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000).

Neuropsychological evidence points to both unity and fractionation of executive functions (Miyake et al., 2000; Pessoa, 2009). Three executive functions that have been clearly identified in the scientific literature are inhibition, shifting, and updating. According to Pessoa (2009), these functions are mutually interacting, and this

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interaction may lead to executive competition (i.e. trade-offs in the amount of resources devoted to each function). However, different executive functions are also likely to contribute differentially —and perhaps uniquely— to higher order cognitive tasks (Miyake et al., 2000). Therefore, the use within the same study of a combination of tasks is probably the best way to gauge a fuller array of WM multiple functions.

Working memory and writing

Cognitive models of writing have placed considerable emphasis on how WM mediates planning, translation, and revision. However, only Kellogg's (1996) model provides a more comprehensive account of how different WM components are activated during writing and, indeed, this model has been used as a theoretical framework in both L1 and L2 writing studies.

Drawing on Baddeley's multicomponent model, Kellogg argued that planning requires the visuospatial sketchpad to mentally visualise and construct ideas, whereas the central executive is responsible for their processing and coordination. The translation of ideas into appropriate sentences places demands on both the phonological loop and the central executive. In particular, the phonological representations of the units of a sentence are actively maintained, processed, and rehearsed within the phonological loop. Controlled search processes are also engaged in order to access and select the target linguistic features; these processes are believed to be more taxing of executive functions. Transcription and motor execution do not engage WM resources, at least in the case of adult writers who have automatised handwriting skills as opposed to children. Finally, monitoring of the linguistic output entails reading processes that tap into the phonological loop, as well as error detection which makes use of the

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visuospatial sketchpad.

Kellogg's model is perhaps the only one to provide testable hypotheses about the role of WM in writing. Nevertheless, the model was grounded in experimental data derived from L1 writing studies that mainly used the dual- and triple-task paradigms. This raises a number of questions regarding its suitability as a theoretical framework in L2 writing studies, particularly when the focus is on the product rather than the process, or when different methodological paradigms are used. Furthermore, it was based on Baddeley's multicomponent model, thus, an update or refinement is needed in order for its accommodation into the current neuropsychological advances in the study of WM (Mavrou, 2017).

Working memory in L2 writing studies

Comparatively little research has addressed the role of WM in L2 writing, and the findings of the studies that do exist point to pronounced discrepancies. For instance, there is evidence to indicate that WM capacity (WMC) is positively linked to overall writing quality (Mavrou, 2018a, 2018b; Osle Ezquerra, 2012), specific measures of writing performance (i.e. accuracy and syntactic complexity) in complex versions of L2 writing tasks (Bergsleithner, 2010; Zalbidea, 2017), and lexical sophistication, use of connectives, and fluency in academic writing (Révész, Michel, & Lee, 2017). However, other studies have shown that the L2 proficiency level mediates the strength of correlation coefficients between WMC and L2 writing performance (Kormos & Sáfár, 2008) and that both L2 aptitude (Sáfár & Kormos, 2008) and L2 proficiency level (Lu, 2010; Mavrou & Bustos-López, 2019) might be better indicators of L2 writing quality. Trade-offs between fluency and subclausal elaboration in L2 writing have also been

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reported but only among low WMC learners (Mavrou, 2018c). Another line of evidence further suggests that the influence of WMC on L2 writing might be dependent —at least to some degree— on task type, task complexity, and learners' grade level (Michel, Kormos, Brunfaut, & Ratajczak, 2019).

The aforementioned studies have made promising attempts at elucidating possible ways in which WMC is involved in L2 writing. However, they almost exclusively adopted a cognitive approach and scant —if any— attention was paid to emotion-related variables that may also influence L2 writing outcomes. Moreover, a systematic comparison of their findings is particularly challenging because of the varied WM tasks employed in these studies. In this regard, it is important to keep in mind that not all WM tasks tap into the same processes and content domains, and scores derived from most —if not all— WM measures include systematic variance due to other nonexecutive cognitive processes involved in these tasks; this is the so-called *task impurity problem* (Miyake & Friedman, 2012; Miyake et al., 2000). For example, the Sentence Span Task —used in Osle Ezquerra's (2012) study— requires reading comprehension processes, the Operation Span Task —employed in Lu (2010), Osle Ezquerra (2012), and Révész et al. (2017)— relies on arithmetic operations, whereas performance in the Listening Span Task (Mavrou, 2018a) depends on individuals' ability to process and judge the grammaticality of oral sentences. Performance in these complex span tasks also depends on rehearsal processes, task-related features (e.g. length and complexity of the oral or written sentences), and individuals' metalinguistic skills (Ivanova & Hallowell, 2014). Thus, correlations —or lack thereof— between WMC assessed by these and other complex span tasks and measures of L2 writing performance should be interpreted in light of the specific processes and content domains that these tasks are supposed to

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measure. This is not usually the case, as inferences and interpretations that stem from research into L2 writing mainly rely on the most common —if perhaps oversimplified— conceptualisation of WM (i.e. the simultaneous storage and processing of information), neglecting the role of specific executive functions.

On the other hand, short-term memory, WM, and executive functioning tasks also capture some similar or overlapping memory processes and functions. Indeed, there is abundant evidence for moderate to strong correlations between performance in simple and complex span tasks (Colom, Rebollo, Abad, & Shih, 2006; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999; Kane et al., 2004). These correlations suggest that these tasks tap into a common set of cognitive processes, which in turn would explain the high associations between performance in these tasks and performance in cognitively demanding tasks (Colom et al., 2006; Oberauer et al., 2000; Unsworth & Engle, 2006, 2007a). However, the available evidence indicates that correlations between executive functioning tasks and typical complex span tasks are usually not very high.

In sum, a clearer link should be established between L2 writing and distinguishable executive functions (i.e. inhibition, shifting, updating), as well as visuospatial WMC, whose role in L2 writing is rarely studied and is thus less well understood. The present study contributes to this underexplored area of research by focusing on the aforementioned WM functions.

Memory-emotion interactions

As mentioned above, cognition and emotion are interrelated concepts that jointly shape behaviour and action (Pessoa, 2008, 2009; Phelps, 2006). Empirical evidence

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suggests that neural activity in the dorsolateral prefrontal cortex (PFC) —the part of the brain involved in WM and executive control— is enhanced by pleasant images and reduced by unpleasant ones as long as these stimuli place demands on WM (Perlstein, Elbert, & Stenger, 2002). Gray, Braver, and Raichle (2002) also found neural activity in the lateral PFC after presenting to their participants short videos inducing emotional states. This led the authors to the conclusion that this brain structure "is the site of emotion-cognition integration, not merely sensitive to it" (p. 4119). Based on this evidence, Pessoa (2008) argued that executive functions interact with affective variables (e.g. valence of the emotional stimuli) and that the lateral PFC might serve as a "control hub" for the integration of cognitive and affective information. Although the present study does not test whether and how emotion induction affects WM task performance, a plausible hypothesis is that WM might be involved in the retention, processing, and subsequent written storytelling of emotion-inducing material.

It is also believed that WM —particularly its updating ability— is involved in the regulation of emotions (Levens & Gotlib, 2010; Pe, Raes, & Kuppens, 2013; Schmeichel & Demaree, 2010), one facet of emotional intelligence (EI). Broadly speaking, EI refers to the ability to perceive, express, and manage our own and other people's emotions (Mayer & Salovey, 1997; Petrides, 2009; Salovey & Mayer, 1990). Several studies found that higher scores in EI and its specific components (e.g. attention to emotions) are linked to better performance in WM tasks that comprise emotional items (Coffey, Berenbaum, & Kerns, 2003; Gutiérrez-Cobo, Cabello, & Fernández-Berrocal, 2017a, 2017b). In addition, the ability to update emotional content within WM appears to play an important role in the implementation of emotion regulation strategies (Pe, Raes, & Kuppens, 2013; Schmeichel & Demaree, 2010) and in the perceived well-

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being (Pe, Koval, & Kuppens, 2013). It has also been argued that EI is a proxy for emotional granularity (i.e. the ability to describe emotional experiences in a precise manner; Lee, Lindquist, & Nam, 2017) and that high EI individuals are better able to use a wide range of emotion concepts to describe their emotional states and experiences (Barrett, 2017).

Altogether, the existing evidence allows for the proposition of at least two tentative hypotheses: (1) if WM and EI are positively linked —and given the important role of WM in the cognitive processes involved in writing—, their effect in L2 writing might be cumulative; (2) EI is likely to be involved in the description of emotional events and thus account for variability in certain linguistics aspects of emotional discourses (e.g. use of a more diverse vocabulary or more detailed description of the emotional events leading to higher fluency).

Emotional intelligence and L2 writing

The role of EI in L2 writing is admittedly less obvious, and the research design, performance measures, and findings of the few studies conducted to date are not always comparable. Abdolrezapour (2013) found that Iranian English L2 (ESL) learners who carried out emotional activities (literary readings with highly emotional content) and were also introduced to Goleman's EI theory as a pedagogical intervention obtained higher scores in writing as assessed through content, organisation, and language criteria. Similarly, Shao, Yu, and Ji (2013) observed that the use of literature-based activities to raise students' EI had a positive impact on their writing achievement assessed in terms of content, reasoning, expression, grammar, and vocabulary. Ghasemi, Behjat, and Kargar (2013) also reported a moderate correlation between EI and writing

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improvement, although it is unclear how they measured writing ability. Furthermore, Korpi and Farvardin (2016) found that certain branches of EI correlated strongly with specific features of L2 writing (complexity, accuracy, fluency). On the other hand, Farjami and Ghebali (2013) did not find an association between EI and coherence in ESL writing. Surprisingly, most of these studies were conducted with Iranian ESL learners. Thus, it is difficult to assume generalisability across different L2 contexts and target languages.

There is also one study that tackled the potential interaction between WMC, EI, and writing in L2 Spanish. Mavrou and Bustos-López (2019) administered a self-reported measure of EI, three WM tasks, and a writing task based on an emotional topic. Although no statistically significant correlations emerged between WMC and writing quality, participants at the elementary level who scored higher in the repair component of self-reported EI tended to obtain lower writing scores. The authors attributed this result to a potential trade-off between the amount of cognitive resources these students employed in emotion regulation strategies and the time and attention devoted to the linguistic aspects of writing. They also speculated that these participants might have felt more anxious or nervous about the quality of their texts and, therefore, needed more regulatory strategies to mitigate these negative feelings.

The current study

The current study expands on research that focuses on the role of WMC in L2 writing but also extends the scope of inquiry to an underexplored area, that is, the joint effect of WMC and trait EI on L2 writing performance. To this end, five WM tasks were administered. These tasks were chosen based on their capacity to measure both

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storage and processing abilities, as well as different WM functions. The study also employed an audiovisual blended-emotion stimulus as a prompt for written production, thus going beyond traditional approaches to the study of writing, which are based on academic tasks. Writing about emotional events and experiences can be of particular value for L2 pedagogy, as being able to express emotions in an L2 is one of the requirements established by the Common European Framework of Reference for Languages (Council of Europe, 2018). Furthermore, although complexity, accuracy, and fluency (CAF) measures have been widely used in studies that address the role of WM in L2 writing, it is unclear whether these linguistic dimensions are enhanced by a higher WMC or EI (or both) in tasks that require the expression of emotions. Thus, the present study addressed the following question: To what extent are specific WM functions (inhibition, shifting, updating, visuospatial WMC) and trait EI significant determinants of CAF in L2 writing performance prompted by an audiovisual blended-emotion stimulus?

Method

Participants

Participants were 59 learners of Spanish, 12 males and 47 females, aged between 18 and 26 (M = 20.86, SD = 1.49). Most participants were from the USA (n = 26) and China (n = 23), whereas the remaining had the following nationalities: Korean, German, Italian, Dutch, Polish, and British. The mean age of the onset of Spanish acquisition was 16.53 years (SD = 3.54, n = 48). All participants had an intermediate level of Spanish at the time of data collection as established by a placement test, which was conducted by the institution where participants were taking Spanish language courses in an immersion context, and self-reported ratings that participants provided. These ratings assessed their

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listening, oral, reading, and writing skills in Spanish based on a 5-point scale and were included in a brief questionnaire administered to them after they had completed the writing task (mean cumulative score: 11.57 over 20 points, *SD* = 2.16, *n* = 54).

Instruments

Backward Corsi Block-Tapping Task. The Backward Corsi Block-Tapping Task (Kessels, van den Berg, Ruis, & Brands, 2008) is a measure of visuospatial WMC. Participants were presented with a screen of nine boxes that lit up in a pre-fixed sequence and asked to click on the boxes in the reversed serial order. The sequence length started at level 2 (i.e. two boxes lit up) and increased up to level 8. Participants had two tries at each sequence length. If one of the sequences was entered correctly, the next sequence started. A summary score was computed for this task, which was derived from the achieved block span —which was equal to the length of the last correctly recalled sequence— multiplied by the total number of correctly recalled sequences across the whole task (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000). This task, as well as the following four executive functioning tasks, were administered using the Inquisit Lab platform.

Operation Span Task. The Operation Span Task is a widely used task believed to assess either updating or shifting abilities (or both). It was chosen among other complex span tasks because it is less dependent on language-related factors. Moreover, it has been previously used in L2 writing studies as a *global* measure of WMC, rather than as a task that assesses specific executive functions (c.f. Révész et al., 2017). In the present study an automated version of the task was used (Unsworth, Heitz, Schrock, & Engle, 2005) that required participants, as quickly as possible, to solve sets of

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mathematical operations presented visually and followed by a proposed solution and to indicate whether the solution provided was *true* or *false*. An 85% level of accuracy was established for mathematical problem solving (Unsworth et al., 2005). Participants also had to remember sets of three to seven letters in the exact order that they appeared after each mathematical operation and pick these letters from a provided 4 X 3 letter matrix. Two scores were computed: (1) the sum of all perfectly recalled sets, and (2) the total number of all letters recalled in the correct position. Correlation between these scores was very high ($r = .902$, $p < .001$), however, the first score was used in subsequent analyses because its values were normally distributed ($W = .958$, $p = .082$, compared to $W = .892$, $p < .001$, for the total number of letters).

Running Memory Span Task. The Running Memory Span Task (Broadway & Engle, 2010) was chosen as a measure of updating ability. Participants were presented with a series of letters of varying length (from three to eight) and, when prompted, they had to report the last *N* items (from three to six targets) of the list using a 3 X 4 letter matrix. There were six trials for each target length: three without distractors preceding the targets and one trial for each target length with one, two, or three distractors preceding the targets. Both the target lengths and the number of distractors were randomised. At the start of each block participants received information about the number of letters they had to report. The sum of all correctly recalled targets was used as an indicator of participants' updating ability.

Number Letter Task. Shifting ability was assessed with the Number Letter Task (Miyake et al., 2000; Rogers & Monsell, 1995). In this task, pairs of characters appeared in one of the fields of a 2 X 2 matrix (e.g. 3F) and moved in clockwise fashion around the matrix. Participants had to perform two tasks depending on the box in which the

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character pair appeared: (1) a letter task every time the character pair appeared in the top quadrants of the matrix; the character pair consisted of a target letter and a distractor digit, and participants had to press the key E when the target letter was a consonant (G, K, M, R) or the key I when it was a vowel (A, E, I, U); and (2) a digit task every time the character pair appeared in the bottom quadrants of the matrix: the character pair consisted of a target digit and a distractor letter, and participants had to press the key E when the digit was an even number or the key I when it was an odd number. Trials with latencies less than 100 milliseconds were excluded (Rogers & Monsell, 1995). The reaction time switch cost was computed as the difference between the mean correct latency of switch trials and the mean correct latency of non-switch trials. Positive values indicated that participants were slower during switch trials.

Emotional Stroop Task. The Emotional Stroop Task (Smith & Waterman, 2003) assesses the ability to inhibit cognitive interference, although it has also previously been used as a measure of cognitive control ability. It was chosen instead of the traditional Stroop task because previous research has shown correlations between performance in this task and specific branches of perceived EI (Coffey et al., 2003). Participants were presented with affective and neutral words from five categories (aggression, neutral, positive, negative, and colour words) in coloured font (blue, red, yellow, green) and had to press, as quickly and accurately as possible, one of four response keys to indicate the colour of each word disregarding its meaning or emotional connotation. Mean latencies for correct responses in all five categories were computed separately but only the colour word category was used in subsequent analyses.

Trait Emotional Intelligence Questionnaire. Trait EI (TEI) was measured through the Trait Emotional Intelligence Questionnaire – Short Form (TEIQue-SF;

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Petrides, 2009). The TEIQue-SF is comprised of 30 items that tap four self-perceived facets of EI, namely, well-being, self-control, emotionality, and sociability. Participants indicated their agreement with each item by using a 7-point Likert scale ranging from 1 (*completely disagree*) to 7 (*completely agree*). Reliability analysis suggested acceptable internal consistency (Cronbach's α = .881).

Writing task. The writing task was based on the animated 11-minute short film *Cuerdas*, written and directed by Pedro Solís García, which was awarded the Goya Award in 2014 for Best Spanish Animated Short Film. The story takes place at an orphanage where two children, Maria and a boy who suffers from cerebral palsy, become friends. When they play together, Maria tries to help her friend move his arms and legs using a string ('*cuerda*'). But one day, Maria finds a piece of string on her friend's wheelchair, similar to the one she used when she played with him, and realises that her friend has passed away. Twenty years later, Maria becomes a teacher at the same orphanage and wears a piece of string around her wrist as a memory of her friend. The story can elicit a blend of emotions, including hope, admiration, tenderness, compassion, and sadness.

After participants watched the film, they were asked to describe the plot of the story and express how they felt about it. They were given the following prompt translated into Spanish: "*Tell what happened in the story and try to provide details: who were the main characters, what happened in the story and specifically what feelings or emotions the story evoked in you? It is important that you tell the story using the past tenses*". Participants had 20 minutes to complete the writing task by hand. They were also told to indicate on a 7-point semantic differential scale whether, in their opinion, the film was happy or sad and positive or negative. As expected, there was variability in

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their answers: 64% of the participants assessed the film as sad but, at the same time, 74.5% judged the film to be positive. These data are indicative of the blended-emotion messages the film was able to transmit.

CAF measures. Complexity, accuracy, and fluency (CAF) are considered to be "the primary epiphenomena of the psycholinguistic processes and mechanisms underlying the acquisition, representation and processing of L2 systems" (Housen, Kuiken, & Vedder, 2012, p. 2). It has been argued that these measures satisfactorily capture L2 learners' general language proficiency (see Housen & Kuiken, 2009, and Wolfe-Quintero, Inagaki, & Kim, 1998, for comprehensive definitions of these constructs). For syntactic complexity, three measures were used: the subordination index, the mean length of clause, and the mean length of t-unit. These measures were chosen in order to assess different dimensions of the construct (i.e. complexity via subordination, overall syntactic complexity, and subclausal complexity via phrasal elaboration; Norris & Ortega, 2009). Lexical complexity was assessed with Dugast's Uber index and a measure of lexical variation computed as the total number of lexical types divided by the total number of lexical tokens (Jarvis, 2002; Wolfe-Quintero et al., 1998). Accuracy was operationalised as the proportion of correct words with respect to grammar and lexical choices. Spelling errors were not taken into account, unless they concerned accent marks in verbal endings of past tenses (e.g. use of the first-person singular of present indicative *ayudo* instead of the third-person singular of simple past *ayudó*). Finally, fluency was assessed with the total number of tokens, t-units, and clauses (Wolfe-Quintero et al., 1998). Since all participants made use of the full time allotted for the completion of the task, time-based fluency measures were not employed (see Mavrou, 2018c, for detailed guidelines and examples of the coding procedure). The

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texts that participants produced were analysed as a whole (i.e. without distinguishing between storytelling and expression of emotions) as emotions and feelings alternated with the storytelling and emerged at different parts of participants' discourse.

Procedure

Participants were informed about the general purpose and procedures of the study and their right to refuse to participate, engage in certain tasks, or withdraw without any consequences. Task administration took place in two sessions. The first session involved a paper-and-pencil questionnaire and task. After watching the film *Cuerdas*, participants completed the writing task, the TEIQue-SF, and a brief questionnaire about their linguistic profile during class hours. WM tasks were administered in a second session after appointments were held individually with each student. The five WM tasks were all visual and started with a practice session that allowed participants to familiarise themselves with the equipment —a 13-inch MacBook Pro laptop— and the tasks' requirements.

All participants completed the writing task and the TEIQue-SF, except for one student who did not complete many items of the TEIQue-SF, making it impossible to calculate her TEI score. Another four participants did not complete any of the WM tasks, but they did complete the writing task and the TEIQue-SF. Data from one participant in the Running Memory Span Task, one in the Emotional Stroop Task, and two in the Number Letter Task were lost due to equipment malfunction, while data from six participants in the Operation Span Task were excluded because they failed to reach the 85% level of accuracy in the processing component of the task. Therefore, the statistical analyses relied on a slightly different number of observations. The Emotional

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Stroop Task was the only language-based WM task comprised of English words. Although not all participants' L1 was English, an independent samples t-test showed no statistically significant differences in task performance between English L1 participants and those whose L1 was not English ($t = 1.856$, $p = .069$). Statistical analyses included both classical and Bayesian methods (see Wagenmakers, 2007, for a comprehensive account of the advantages of the Bayesian approach over null hypothesis significance testing) and were performed using SPSS v.23.0 (IBM Corp., 2015) and JASP v.0.12.2 (JASP Team, 2020).

Results

Descriptive statistics for all tasks were initially estimated (Table 1). All measures had relatively low skewness values, whereas kurtosis values were acceptable in most cases (i.e. less than 2; Kline, 1998). High kurtosis values were observed for scores in the Emotional Stroop Task, t-units, and lexical variation but were mainly attributable to one single outlier in each case; thus, they were retained in the analyses following Stevens' (2009) recommendations. WMC scores were also screened for multivariate outliers using Mahalanobis distance but no such outliers were found.

Table 1
Descriptive statistics for WMC, TEI, and CAF measures

	M	SD	Skewness	Kurtosis
Backward Corsi Task	57.11	15.31	0.64	1.13
Operation Span Task	51.10	15.25	-0.66	0.03
Running Memory Span Task	34.87	8.31	-0.11	-0.36
Number Letter Task	662.45	267.78	0.58	0.02
Emotional Stroop Task	816.13	193.37	-1.06	4.73
Trait Emotional Intelligence	4.95	0.72	-0.20	-0.61
Words	162.20	52.39	0.52	0.80
T-Units	17.93	5.62	1.23	3.59
Clauses	24.80	8.03	0.85	1.05
Subordination Index	1.39	0.21	0.34	-0.13
Mean Length of T-Unit	9.13	1.73	0.62	1.53
Mean Length of Clause	6.58	0.97	1.12	1.34
Accuracy	88.31	4.96	-0.55	-0.04
Uber Index	15.01	1.99	0.68	0.85
Lexical Variation	0.67	0.11	1.14	4.18

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Preliminary exploratory factor analyses were run separately for WMC scores (Table 2) and CAF measures (Table 3). Common factor analysis was deemed more appropriate for studying latent variables (WM functions), while principal component analysis was chosen to examine linear composites of the CAF measures (Fabrigar, Wegener, MacCallum, & Strahan, 1999). Correlations between factors derived from WMC scores and between components derived from CAF measures were theoretically justified and empirically expected; therefore, oblique rotation methods, which are believed to provide more realistic and reproducible factor solutions, were employed (Conway & Huffcutt, 2003; Costello & Osborne, 2005; Fabrigar et al., 1999).

Table 2
Common factor analysis for WMC scores

	Factors		
	1	2	3
Operation Span Task	.762	-.072	.052
Running Memory Span Task	.701	-.130	.267
Number Letter Task	.390	.382	-.094
Emotional Stroop Task	-.081	.509	.032
Backward Corsi Task	.034	.031	.424
% Variance after extraction	29.726	9.600	2.550
Eigenvalues after rotation	1.419	0.462	0.656
Kaiser-Meyer-Olkin Test	.577		
Bartlett' Test of Sphericity	$\chi^2 = 32.273$	gl = 10	$p < .001$

Note. Extraction method: Principal axis factoring; Rotation method: Oblimin direct.

Table 3
Principal component analysis for CAF measures

	Components			
	1	2	3	4
T-Units	.964	-.296	.041	-.038
Words	.960	.200	.057	.070
Clauses	.906	.099	.024	-.105
Mean Length of T-Unit	.088	.923	.020	.181
Subordination Index	-.075	.884	.014	-.217
Accuracy	.054	.017	.986	-.037
Uber Index	.025	.012	-.066	.979
Lexical Variation	-.444	-.090	.200	.611
% Variance after extraction	46.818	21.453	15.515	8.777
Eigenvalues after rotation	3.440	1.880	1.155	2.174
Kaiser-Meyer-Olkin Test		.538		
Bartlett' Test of Sphericity	$\chi^2 = 580.095$	gl = 28	$p < .001$	

Note. Extraction method: Principal component analysis; Rotation method: Oblimin direct.

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Regarding WMC scores, although a 2-factor solution was plausible, a forced 3-factor solution accounted for a slightly higher percentage of the explained variance and provided more interpretable results. The Operation Span Task and the Running Memory Span Task loaded highly on the first factor ($\lambda > .70$). This result is consistent with previous findings (Miyake et al., 2000; Wilhelm, Hildebrandt, & Oberauer, 2013), suggesting that the Operation Span Task primarily implicates the updating ability or general WM functions related to updating. Thus, in subsequent analyses a composite score of these two measures was created (i.e. an average of standardised values) and used as an indicator of participants' updating ability. Factor 2 consisted of scores on the Emotional Stroop Task and the Number Letter Task, although the latter presented moderate cross-loadings between the first and second factors. This finding might indicate that the ability to shift among different tasks or mental processes efficiently and flexibly requires both the updating ability and the inhibition of cognitive interference. Finally, the Backward Corsi Task only had a moderate loading on the third factor. Although any conclusion would be premature due to the small number of observations and WM tasks, the factor solution that emerged is in line with the view that the three target executive functions (inhibition, shifting, updating) are not completely independent nor completely overlapping (Miyake et al., 2000). For the Emotional Stroop Task, the Number Letter Task and the Backward Corsi Task, standardised scores were also calculated and used in the remaining analyses.

For CAF measures, several principal component analyses were conducted until the most plausible and interpretable structure was reached. The mean length of clause turned out to be a complex variable and was excluded from the analyses. This decision was reinforced by the findings of a previous study (Mavrou & Ainciburu, 2019) that

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showed that the mean length of clause behaves differently compared to other global measures of syntactic complexity and that it might even assess a different construct. The first component was composed of measures of written fluency; the second component comprised measures of syntactic complexity; the single accuracy measure used in the study loaded highly on the third component; and measures of lexical complexity loaded higher on the fourth component. All loadings were above .70, except for lexical variation whose loading was slightly lower (λ = .611). Based on these findings, composite scores were created using Bartlett's method (see DiStefano, Zhu, & Mîndrilă, 2009, for a discussion of the advantages of this method) to further examine the relation between WMC, TEI, and CAF measures.

Pearson product-moment correlations revealed four meaningful correlations representing medium effect sizes. Bonferroni correction was not used due to several issues with this method for adjustments of statistical significance (Perneger, 1998). Bayes factors were also estimated in order to examine the fit of the data under the alternative hypothesis (H_1: $\rho \neq 0$) compared to the null hypothesis (H_0: $\rho = 0$). Updating ability correlated negatively with TEI (r = -.306, p = .034, [-.543, -.024], BF_{10} = 1.584, weak evidence for H_1) and positively with accuracy (r = .435, p = .002, [.172, .640], BF_{10} = 18.349, strong evidence for H_1). Participants with higher ability to inhibit interference tended to produce less syntactically complex texts (r = .331, p = .013, [.072, .548], BF_{10} = 3.293, moderate evidence for H_1). A closer inspection of the data showed that the above correlation was higher for the subordination index (r = .320, p = .017, [.059, .539], BF_{10} = 2.644) compared to the mean length of t-unit (r = .281, p = .038, [.017, .509], BF_{10} = 1.382). A positive correlation also emerged between the subordination index and updating ability (r = .321, p = .026, [.040, .554], BF_{10} = 1.978).

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Finally, a trade-off was observed between fluency and lexical complexity (r = -.405, p = .001, [-.599, -.166], BF_{10} = 22.643, strong evidence for H_1). Partial correlation analyses were also conducted to control for age, as a large body of evidence points to age-related declines in measures of cognitive functioning (Salthouse, 2010). The results were almost identical and are thus not reported here.

A series of linear regression models were also carried out in order to gain greater insight into the correlation patterns observed. Considering the magnitude of the correlation coefficients, regression models were run only for the subordination index (Table 4) and linguistic accuracy (Table 5). In absence of a theoretical framework that would allow for specific predictions about the role of executive functions in L2 writing, the backward elimination method was deemed more appropriate for exploratory model building (Field, 2009). Bayesian methods were also used in order to assess the plausibility and predictive performance of different candidate models and avoid the problem of overfitting.

Table 4

Contribution of WMC and TEI to the subordination index

Model		B	SE B	p	F	R^2	Adj. R^2	BF_{10}
1	(Intercept)	1.250	0.195	< .001	2.810	.255	.164	1.541
	Visuospatial	0.047	0.028	.100				
	Shifting	0.036	0.031	.242				
	Inhibition	0.038	0.029	.200				
	Updating	0.073	0.036	.051				
	TEI	0.022	0.039	.567				
2	(Intercept)	1.361	0.027	< .001	3.485	.249	.178	2.996
	Visuospatial	0.046	0.028	.108				
	Shifting	0.035	0.030	.259				
	Inhibition	0.040	0.029	.171				
	Updating	0.068	0.035	.058				
3	(Intercept)	1.365	0.027	< .001	4.179	.226	.172	4.271
	Visuospatial	0.044	0.028	.123				
	Inhibition	0.048	0.028	.099				
	Updating	0.080	0.034	.022				
4	(Intercept)	1.368	0.028	< .001	4.868	.181	.144	4.142
	Inhibition	0.047	0.029	.109				
	Updating	0.092	0.033	.008				
5	(Intercept)	1.367	0.028	< .001	6.810	.131	.112	4.161
	Updating	0.088	0.034	.012				

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Table 5
Contribution of WMC and TEI to accuracy

Model		B	SE B	p	F	R^2	Adj. R^2	BF_{10}
1	(Intercept)	0.140	0.979	.887	2.484	.233	.139	0.957
	Visuospatial	0.091	0.141	.522				
	Shifting	-0.267	0.154	.089				
	Inhibition	0.044	0.147	.768				
	Updating	0.532	0.182	.005				
	TEI	-0.034	0.195	.862				
2	(Intercept)	-0.030	0.136	.827	3.171	.232	.159	2.050
	Visuospatial	0.094	0.139	.502				
	Shifting	-0.265	0.151	.087				
	Inhibition	0.041	0.144	.780				
	Updating	0.540	0.174	.004				
3	(Intercept)	-0.032	0.134	.813	4.294	.231	.177	4.760
	Visuospatial	0.094	0.137	.498				
	Shifting	-0.255	0.146	.087				
	Updating	0.533	0.171	.003				
4	(Intercept)	-0.024	0.133	.857	6.283	.222	.187	10.743
	Shifting	-0.261	0.144	.078				
	Updating	0.562	0.164	.001				
5	(Intercept)	-0.034	0.134	.803	10.717	.189	.171	8.874
	Updating	0.516	0.158	.002				

Updating accounted for the greatest portion of variance in the subordination index and remained the only statistically significant predictor in nearly all models. Bayesian analysis suggested that the data were 4.16 times more likely to occur under a model that included only the updating ability. In addition, the results confirmed the significant effect of updating on linguistic accuracy, with beta coefficients being statistically significant at the .01 level in all models. Shifting ability also contributed to the increase of the explained variance. For instance, updating and shifting explained 22.2% of the variability in linguistic accuracy, and the Bayes factors of Models 4 and 5 suggested substantial evidence for the role of these two executive functions in linguistic accuracy.

Discussion

The present study investigated whether WMC and TEI are significant determinants of syntactic and lexical complexity, accuracy, and fluency in L2 writing

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prompted by an audiovisual stimulus eliciting blended emotions. Among the target executive functions, updating (i.e. the ability to modify or replace old and current memory traces with new information) proved to be the best predictor variable of two linguistic dimensions, namely, subordination density and linguistic accuracy, and these findings were roughly supported by both classical and Bayesian methods.

Ferreira and Engelhardt (2006) argued that decisions about which syntactic structures are used in a specific context depend on the accessibility of the lemmas required. To access these lemmas, L2 learners have to carry out controlled search processes in order to activate, retrieve, and temporarily maintain in WM these lemmas until their subsequent orthographic transcription. Producing L2 texts with high subordination density also demands decisions regarding verb mood, subordinating conjunctions, agreement relations, as well as decisions about how the linguistic elements will be combined and ordered within an utterance, among others. All these features introduce a high degree of cognitive complexity, especially when L2 proficiency level is low.

It has been argued that individual differences in WMC represent differences in controlled processing ability and are manifested to a greater degree when cognitive load is high (Kane et al., 2007); for example, when L2 learners try to produce syntactically complex written discourse. Miyake and Friedman (2012) speculated that the updating ability may reflect two mechanisms: effective gating of information and controlled retrieval from long-term memory. Therefore, L2 learners with high updating ability might be more efficient at accessing —through controlled search processes— and retrieving from long-term memory syntactic patterns, lemmas, and declarative knowledge related to the syntactic linkage through subordination. This assumption fits

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well with Ferreira and Engelhardt's (2006) argument that production is incremental and this feature "reduces the computational burden on the grammatical encoder because the system can begin with what is already accessible and wait for other elements to become available as processing unfolds" (p. 83). In order for these elements to become available, at least some updating of the information is required.

Regarding accuracy, the results are in line with empirical evidence suggesting that grammatical, phonological, and orthographic encoding rely on WM resources (Fayol, Largy, & Lemaire, 1994; Hupet, Fayol, & Schelstraete, 1998; Kellogg, Olive, & Piolat, 2007; Olive, Kellogg, & Piolat, 2008). Again, updating ability contributed substantially to the variability observed in linguistic accuracy, followed by shifting ability. Jonides and Smith (1997) argued that executive processes are responsible for the lower-level computational processes performed on the contents of WM. Linguistic accuracy could also be conceptualised as the result of several computations that operate first on individual linguistic elements or combinations of these elements (e.g. chunks) and later at a more global level (e.g. clause, utterance, paragraph). Following Jonides and Smith (1997), these computations would include: (1) accessing and retrieving from long-term memory, through controlled search processes, the linguistic elements needed to create an utterance; (2) among these linguistic elements, choosing the most appropriate ones and inhibiting the irrelevant items from the focus of WM; (3) searching long-term memory for grammar rules and applying this knowledge to the current contents of WM; (4) consistently updating the WM contents so that the remaining necessary items become the focus of attention; (5) scheduling operations such as correct word order; (6) setting priorities (e.g. after writing down the utterance, evaluate cohesion and coherence). Although extremely simplistic, this example illustrates that linguistic

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accuracy is a matter of multiple and complex computations regarding the contents of WM. It is possible that some of these computations —such as (1), (3), and (4), which are directly linked to the mechanisms that Miyake and Friedman (2012) proposed as key for updating ability— are particularly important for L2 writing accuracy. Shifting would also take place in order to create error-free linguistic units or detect errors, for example, by switching between mental processes related to long-term memory searches and retrieval and by going back and forth between different parts of the text in order to decide the appropriate syntax, word location, subject-verb and object-verb agreement.

Contrary to WMC, TEI had a negligible effect on CAF measures. The fact that participants did not receive any emotion-based pedagogical intervention prior to the writing task and that writing quality was assessed with (psycho)linguistic rather than discourse-based criteria could somewhat account for the discrepancies between the results obtained here and the findings of previous studies (Abdolrezapour, 2013; Shao et al., 2013). However, the lack of statistically significant correlations does not rule out the possibility that EI is involved in writing, and particularly in writing about emotional topics. One hypothesis that can be put forward and tested in the future is whether EI plays a role in L2 emotional written discourses as assessed through specific emotion-based criteria (e.g. number and valence of emotion words).

Another intriguing finding concerns the negative link between TEI and updating ability. This result is quite difficult to explain as it calls into question previous evidence regarding the positive link between EI and executive functions (Pe, Raes, & Kuppens, 2013). It could be that the ability to update —and constantly recycle— much of the information stored in WM could have adverse outcomes in particular situations. As Barrett, Tugade, and Engle (2004) argued, “those higher in WMC may have the ability

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to sustain a focus on negative circumstances and to 'resist distraction' from positive information" (p. 566). On the other hand, high EI individuals might process emotional information at a deeper level or a slower pace (i.e. they update less) and this could help them filter the information more efficiently and place more focus on their positive experiences. Nevertheless, the present study did not employ an emotional updating task as Pe, Raes, and Kuppens (2013) did, nor did it investigate emotion regulation ability, and the data only provided weak support for the negative link between TEI and updating ability. Thus, it is difficult to draw conclusions regarding the way high and low updating ability individuals process emotional information.

Lastly, a trade-off was observed between fluency and lexical complexity. Retrieving and using a large number of tokens does not necessarily imply the retrieval and use of a large number of types. In addition, although a large vocabulary increases the chances that it will be used in a varied manner, lexical complexity and variation provide an indication of the efficiency with which learners express their ideas using their actual vocabulary knowledge, and learners who are able to vary their discourse are not always those with larger vocabularies (Laufer, 1994; Laufer & Nation, 1995). The topic of writing might also have influenced the trade-off between fluency and lexical complexity. Describing emotional events and expressing emotions in an L2 is not an easy task; it requires specific vocabulary that might not be immediately available when writing is carried out during a short interval and without the use of dictionaries. Thus, attention to lexical choices might have slowed down writing speed, leading to the production of shorter texts.

Conclusions

The present study provides support for the hypothesis that specific executive

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functions are differentially involved in L2 writing. The findings argue strongly for the important contribution of the updating ability to subordination density and linguistic accuracy in L2 writing. They further suggest that TEI plays a minimal role in the psycholinguistic properties of L2 written texts.

Pedagogically speaking and as opposed to oral production, the written trace serves as a memory aid (Olive & Passerault, 2009), which facilitates proofreading and can help writers increase the degree of syntactic sophistication in their discourse. However, L2 students with low updating ability might need more time and cognitive resources to do so. This needs to be taken into account in L2 assessment contexts where speed, time pressure, and the subsequent anxiety provoked may block WMC, with low updating ability L2 students potentially being in a more disadvantageous position. That said, L2 teachers should instruct these students to initially produce simpler grammatical structures and progressively complexify them, and also to develop and practice error correction strategies so that the amount of information that needs to be held and updated within WM is reduced. Rehearsal strategies should also be embraced in L2 classes as rehearsal is necessary for both updating and retrieval processes (Artuso & Palladino, 2019) and has a facilitative role in various aspects of writing (organisation of verbal data in a sequence, text structuring, error correction; see De Guerrero, 1987). Moreover, neuropsychological evidence (Schweizer, Grahn, Hampshire, Mobbs, & Dalgleish, 2013; Xiu, Zhou, & Jiang, 2016) suggests that WM is implicated in affective control. Therefore, future work should try to elucidate whether WM training can be transferable to academic (and particularly writing) tasks or even lead to more generalised benefits (e.g. the use of efficient emotion regulation strategies to overcome the cognitive overload, pressure or other negative feelings that often emerge during writing).

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The present study is not without limitations, which must be acknowledged and adequately addressed in future work. For instance, the study exclusively focused on learners of Spanish, had a moderate sample size, and used only one writing task. Follow-up studies should assess whether the results can be generalised to learners of different linguistic and psychological profiles and to a wider range of emotion-based writing tasks. In addition, the product-oriented perspective and the cross-sectional research design of the current study do not provide any information about L2 writing processes *per se* or the differential contribution of executive functions to L2 writing development across time. Regarding the linguistic indicators of the study, only a small set of CAF measures were employed, and these were manually coded by the researcher; for this reason, it was impossible to perform an interrater reliability analysis. Moreover, new studies should include both self-reported and ability-based measures of EI and further investigate whether and how EI, as well as the topic of writing, affect the emotional properties of L2 written texts.

As outlined in the introduction, writing is a cognitive, affective, and social phenomenon (Brand, 1987; Hayes, 1996). The field of applied linguistics lacks a compelling theory of how emotion and cognition are conjointly involved in different L2 writing contexts and tasks but “[N]o theory can be complete that does not include all of these components” (Hayes, 1996, p. 5). The development of such a theory demands and awaits future research, and as Brand (1987) rightly argued, “[U]nderstanding the collaboration of emotion and cognition in writing is both fundamental and far-reaching. It is in cognition that ideas make sense. But it is in emotion that this sense finds value. Without such priorities we could not think” (p. 442).

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