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A network analysis on digital media use, reading enjoyment, and orthography precision in a highly educated sample

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Authors contribution

Laura Miccoli: Data curation, Formal analysis, Visualization, Writing - original draft; María Ángeles Peña Arias: Software, Investigation, Resources, Data curation, Formal analysis; Julio Santiago: Conceptualization, Methodology, Writing - review and editing, Supervision, Project administration.

ABSTRACT

At least a decade before the advent of smartphones, alarms rose about a diffuse worsening of literacy because mobile phone use appeared frequently accompanied by deviations from standard linguistic norms. Evidence, however, has been mixed and, in addition, several key studies were performed before the current ubiquitous use of online entertainment. The present study used a network approach (partial correlation networks) to examine the relations between the participants' use of free time (whether they devoted it to diverse online and/or offline activities), their enjoyment of reading, and their scores in an orthography test, used as proxy for written language skills. The final sample comprised 840 adults, out of which about 86.7% either were studying or had a university degree. Participants' age and their use of social media contributed the most to the network structure: Social media use was linked to both more social as well as more solitary free time activity, but it showed no direct connection with orthographic skills: at least in this highly educated sample, the relation between written language skills and digital media use was moderated by other factors. Orthographic skills improved, through separate routes, with years of education and with number of books read in a year. As the latter was also strongly associated with subjective reading enjoyment and devoting free time to reading, the findings therefore also indicate that greater reading pleasure significantly contributes to better written language skills.

Keywords from the list: Cultural and social implications, Post-secondary education, Social Media, 21st century abilities.

1. INTRODUCTION

For better or worse, we are anytime and anywhere digitally connected. Over the past decades personal computers and the internet have prompted the ongoing digital revolution. However, it is only since 2012 that smartphones have become prevalent, changing our daily lives and habits (European Commission, 2020). In this context, the emergence of social media has been greeted with enthusiasm by some (J. L. Clark et al., 2018; Ito et al., 2019), yet concern by others, who point at cyber-related inappropriate behaviors and contents (Uhls et al., 2017) and a decline in well-being (Aalbers et al., 2019; Boer et al., 2020; Boniel-Nissim et al., 2022; Uhls et al., 2017) and health (Horowitz-Kraus & Hutton, 2018; Jasbi et al., 2022) linked to frequent social media and smartphone use. Language proficiency has been an area of particular unease, even before the advent of smartphones: The frequent use of *textisms* – deviations from linguistic norms, e.g., "don", "LOL", ":)"– (Rosen et al., 2010), the switch to non-linear reading strategies (Liu, 2005), the predominance of shorter, simpler texts, also in higher education (Baron & Mangen, 2021), have triggered alarms, exaggerated by the press, over a generalized worsening of literacy (Thurlow, 2006).

Academic research on the relations between digital media use and linguistic skills have examined several aspects of language processing, i.e., syntax and grammar; lexis; spelling, textisms, and orthography; semantics; reading fluency; reading comprehension; and writing productivity and text composition (Cingel & Sundar, 2012; Delgado et al., 2018; Mol & Bus, 2011; Rosen et al., 2010; Torppa et al., 2020; Verheijen & Spooren, 2021; Wood et al., 2014). In the present study we decided to focus on orthography, using it as a proxy for written language skills, because of its linguistic and social significance. First, despite being a lower order skill that needs to

be consolidated with vocabulary, knowledge, and intelligence (Hirsch, 2003; Hulslander et al., 2010; Nagy et al., 2022), orthography is pivotal to reach language proficiency (see, e.g., Mol & Bus, 2011): no good writer can get away with having misspellings. Second, it has been argued that orthography "both indexes and constitutes social hierarchies, identities and relationships" (Jaffe et al., 2012).. People do use perceived orthographic skills to classify others into more vs. less educated, what in turn carries strong social implications (Jaffe et al., 2012; Parsons & Bynner, 2007; Pasqualotto et al., 2022).

1.1. Mixed and updatable findings.

Previous literature on the relation of orthography and digital media use is scarce and provides mixed findings. Two studies reported that greater digital media use covaried with a worsening in orthography (Cingel & Sundar, 2012; Rosen et al., 2010) and another study found, but did not further test, that in children and undergraduates some textisms were linked to worse orthography (Wood et al., 2014). However, the picture is far from clear, as other studies have reported a null effect (Drouin & Davis, 2009; Grace et al., 2015) or even an improvement (Verheijen & Spooren, 2021). In addition to the ambiguous and scarce findings, extant data were mostly collected before the advent of social media and smartphones, emphasizing the need to reevaluate the relation between written language skills and current use of online entertainment. Furthermore, methodologically, previous research focused on factors that were specific to linguistic skills and digital media use and did not examine whether orthographic skills are also related to the participants' general use of free time (Thulin et al., 2020; Thulin & Vilhelmson, 2019; Twenge et al., 2019; Vilhelmson et al., 2018), i.e., whether participants devote more time to online or offline leisure activities (like playing video games or reading at will).

The current study aims to verify and expand on previous findings, many of them observed before the advent of massive and ubiquitous digital media usage, by using a network approach (see below) statistically capable of analyzing a wide array of variables, directly or indirectly related to our research focus. We therefore investigate some main factors –demographics, use of time, reading-related variables–, each involving several specific indices. Some of these main factors emerged as central for our goal: 1) Free time activities; 2) Age and education; and 3) Reading enjoyment.

1.2. Free time activities.

Investigating digital media use required a detailed look at participants' use of free time, considering both recently popular online entertainment (Youtube, videogames, Netflix...) as well as more traditional leisure activities (doing sports, watching TV, reading...). Since the studies by Rosen et al. (2010) and Cingel and Sundar (2012), leisure activities have changed considerably: researchers report, for example, less outdoor activities/sports among high social media users (Thulin & Vilhelmson, 2019), less reading and offline hobbies (Vilhelmson et al., 2018), and less face-to-face interactions (Thulin et al., 2022; Twenge et al., 2019). We aim at updating those seminal findings regarding the relation of orthography precision with a range of leisure activities, with a special focus on digital media use. Amusements provided by digital media have greatly expanded since then, some requiring more (e.g., Whatsapp or Facebook) or less reading and/or writing (e.g., Youtube or video games) and possibly relating differently to language proficiency (Verheijen & Spooren, 2021). Because these varieties of digital media use are a recent phenomenon, the literature about their correlates is far from abundant. Thus, we assessed the amount of time devoted to some of these varieties and explored their interrelations with our variables of interest.

1.3. Age and education.

Previous studies found that some demographic factors, such as age (e.g., Verheijen & Spooren, 2021; Wood et al., 2014), and education (Rosen et al., 2010; Verheijen & Spooren, 2021), are important moderators of the relation between digital media use and orthography. In the current study only adults were included, but there was enough variation in age to justify the inclusion of this variable in the analysis. Moreover, the rapid pace of adoption of new ways of online entertainment implies that even small differences in age may be associated to important differences in patterns of use. As for the role of education, Rosen et al. (2010) found that when less educated participants used more textisms –deviations from normative language– their orthographic skills worsened, whereas in participants with higher education orthography was unrelated to textism frequency (see also Drouin & Davis, 2009; Grace et al., 2015).

1.4. Reading enjoyment.

Defined as free voluntary reading (Krashen, 2011) or reading at will, at the time and place that best suits us (Clark & Rumbold, 2006), reading enjoyment has been investigated with diverse indices –e.g., subjective pleasure derived from reading (C. Clark & Rumbold, 2006; Dugdale & Clark, 2008), time spent reading (Horowitz-Kraus & Hutton, 2018), number of books read per year (Mol & Bus, 2011), number of identified popular novels or names of best-selling authors (Mol & Bus, 2011; West & Stanovich, 1991), frequency of reading magazines, comic books, fiction... 'because you want to' (Jerrim & Moss, 2019; Torppa et al., 2020), among others. Reading enjoyment is consistently linked with increased language proficiency and reading comprehension (Delgado et al., 2018; Jerrim & Moss, 2019; Mol & Bus, 2011; Torppa et al., 2020). As mentioned above about orthography, the habit of reading is

linked with better language and knowledge skills that appear to be instrumental in reaching the social advantage of being identified as an educated person (Jaffe et al., 2012; Parsons & Bynner, 2007; Pasqualotto et al., 2022). This may justify the correlations of reading enjoyment with general health and well-being (du Sautoy, 2021; Marshall, 2020; Yates et al., 2016), and why it can help overcome low socioeconomic status (Boonaree, 2015; Dewan, 2016; Krashen, 2020; Krashen et al., 2012). Based on these findings, we expected that reading enjoyment would be linked to both orthographic skills and use of free time, correlating with better orthography and more reading time. In the present study, reading enjoyment was assessed both by asking participants to rate the subjective pleasure derived from reading (Clark & Rumbold, 2006) and by the number of books read per year (Mol & Bus, 2011).

1.5. Study plan

All in all, the present is an openly exploratory investigation of the current state of the pattern of relations between orthography precision and the amount of time devoted to several everyday activities, with a special focus on digital media use and reading habits, as well as with age and education using a highly educated sample. The multifactorial nature of the topic under scrutiny poses the challenge of implementing statistical analyses that can consider complex interrelations between large amounts of variables. In the present study, we rely on partial correlation network analysis (Epskamp & Fried, 2018; McNally, 2021), a recently emerging tool that can reveal both the direct and indirect relations between variables, it is data-driven (so it does not need to hypothesize latent factors), and provides a graphical display of the relations between variables and the strength of their associations (Aalbers et al., 2019; Poikonen-Saksela et al., 2022).

2. METHODS

2.1. Open practices

The survey, raw data, and analysis script, as well as Supplementary Materials and high-resolution figures are publicly available at https://osf.io/6ehkn/?view_only=855b75e4539b47fb86f35cc96e9c074a.

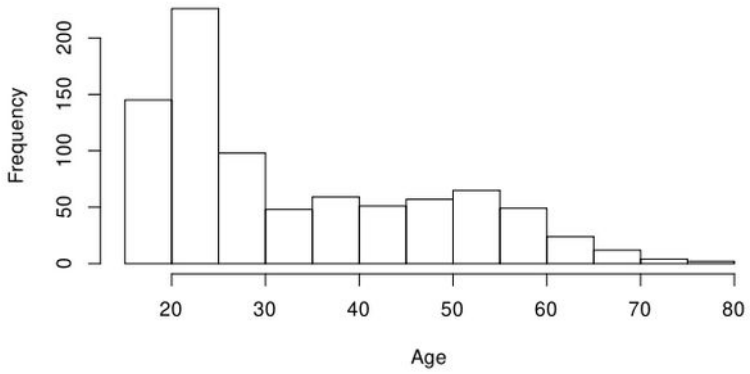
2.2. Participants

The survey was launched on April 20th and closed on June 2nd, 2021, using the University of Granada (UGR) surveys webpage. We defined our target sample as adult Spaniards of all education levels, so non-Spaniards and underage responders were removed. The link to the survey was sent to the whole UGR community through the official mailing list, with pleas to forward it. Thus, a non-probability data collection method was followed, with participants having unrestricted and self-selected access to the survey (Fricker, 2017). The survey was developed, and data were collected online using LimeSurvey (LimeSurvey GmbH, Hamburg, Germany). Data were afterward stored in the UGR servers, complying with the EU General Data Protection Regulation. After reading the study goals and the ethical and privacy standards guiding data management and treatment, the participants provided informed consent. The study protocol was approved by the UGR Ethical Committee (IRB# 2120/CEIH/2021).

Participant characteristics. A total of 1,591 people started the survey. We sequentially excluded participants who did not complete the survey (655), repeated the orthography test (17), were not Spaniards (53), or were underage (26). The final sample consisted of 840 people: 570 were females (66.4%) and median age was 27 years (range 18 - 77). Some participants were at or had completed secondary education (84, 10%), or technical education (28, 3.3%), but most had college-level

education (728, 86.7%); of these, 450 (53.6%) were undergraduates or had completed a university degree, and 378 (45%) had a MSc or PhD degree. The data are consistent with recent online studies conducted in Spain (Salmerón et al., 2020): “the final sample was largely female, middle-aged, and well-educated”.

Figure 1. Age distribution in the sample.



2.3. Measures

Demographic information. Participants reported their gender, age, and nationality.

Education level and academic achievements. Participants reported the highest level they had obtained in the Spanish education system, expressed as completed academic years (9 levels, from 10 years of mandatory education: “I have a mandatory education diploma”, to 19 years: “I have a doctorate”). If they were or had been students, participants were asked to report the grades obtained in their last year of study (5 levels expressed in the usual Spanish scale, from 1: “fail” to 5: “outstanding”). However, for reasons explained below, this measure was not included in the network reported hereby. Finally, participants detailed their degree and university, although these were also not included in the analysis (degree was too heterogenous, with 48 different degrees reported).

Use of time. To investigate how participants spent their time, first they were asked how many hours per day on average, besides classes and work, they devoted to studying and how many they considered "free time" (12 levels, from "zero" to "more than 10 hours/day"). Next, participants were informed that 'reading during free time' was to be defined as reading of texts longer than one page, explicitly excluding short text messages on smartphones or online social networks, and they were asked to report the amount of free time they chose to invest in each of the following activities per day (6 levels, from "zero" to "more than 2 hours"): Reading, using online social networks, watching short videos on YouTube or similar platforms, watching movies or series in platforms like Netflix, watching traditional TV, playing video games, meeting friends in person, meeting friends online, playing sports, or being involved in other leisure activities. Using these items participants reported their use of free time independently for workdays and weekends during the academic course, as well as during vacations (Thulin & Vilhelmson, 2019). Finally, participants were asked to rank the three social networks they used the most, although this factor was also not included in the analysis due to its wide response range.

Reading enjoyment. Additionally to the hours devoted to reading during free time, participants were also asked how much they enjoyed reading on a subjective scale (4 levels, from 1: "I do not enjoy reading at all" to 4: "I enjoy reading a lot") as well as how many books they had willingly read during their free time, approximately, in the past year (6 levels, from 0: "none" to 5: "more than 12 books/year").

Orthography. The orthography test evaluated the participants' conscious or intuitive knowledge of Spanish orthographic norms as described by the *Real Academia Española* (RAE Real Academia Española, 2010). The test was a stringent one. Participants read 56 sentences: half were correctly written; half contained an

orthographic error. Errors could not be detected by autocorrect. Spanish orthography violations concerned grapheme substitutions, word segmentation, graphical accents, use of capital letters, and use of the grapheme "h". Participants had to judge whether the sentence was correctly written or not, and, in case of error, they had to fix it. After data collection, two sentences were excluded from data analysis for being inaccurate, leading to a total of 54 sentences. Orthography scores ranged from 0 to 1 and indicated the proportion of correct answers (1 = no errors).

In the survey, measures were collected in the following order: Orthography test, use of time, reading enjoyment, academic achievements, and demographic information. At the end of the survey, participants were given feedback about their performance in the orthography test, both as an overall score and detailed for each sentence.

2.4. Data preprocessing

All preprocessing and analyses were performed with R (R Core Team, 2020) using the packages *dplyr* (Wickam et al., 2022), *ggplot2* (Wickam, 2016), *corrplot* (Wei & Simko, 2021), *qgraph* (Epskamp et al., 2012), and *bootnet* (Epskamp et al., 2018). All survey measures except age and orthography consisted of Likert items that were z-scaled. Scaling places all items on a common scale and allows the averaging of items that show high correlations, thus reducing the number of variables. Following previous literature (e.g., Lozano et al., 2008; Simms et al., 2019) and in order to run R functions that required that ordinal variables have at most 7 levels, two variables (hours devoted to studying or at leisure, with 12 levels, and completed academic years, with 9 levels) were converted into 6- and 7-levels ordinal variables, respectively. Statistical analyses showed negligible variations as a result of this change.

2.5. Statistical analyses

To analyze and graphically represent the complex interplay between the variables, regularized partial correlation networks were estimated and built (Epskamp et al., 2018; Epskamp & Fried, 2018; Poikonen-Saksela et al., 2022). Regularized partial correlation networks (graphical LASSO) facilitate data interpretation by 1) focusing on factors that contribute significantly to the network while downplaying those only weakly related; 2) identifying direct and mediated relationships[1] between variables; and 3) providing a graphical representation –a network– of the relations between variables.

Following best practice guidelines (Epskamp et al., 2018; Epskamp & Fried, 2018), first, a matrix of partial correlation coefficients was created (*bivariate analyses*); next, the matrix was used to build the network structure that best describes relationships between factors (*network construction*); finally, several steps examined the relevance of each factor within the network (*node importance*) and made sure that the network is an accurate and reliable model of the data (*network accuracy and stability*).

Bivariate statistics. Bivariate relationships between variables were analyzed using Spearman rho correlation coefficients, that best suit self-reported Likert scales and do not assume normality, linearity, and homoscedasticity (McDonald, 2014). Alpha level was set at $p = .05$. Correlations as absolute values were classified within the correlation matrix as weak (.10 to .29), moderate (.30 to .49), or strong (≥ .50).

Network structure. The *qgraph* R package (Epskamp et al., 2012) uses partial correlation coefficients to build a network that displays whether each variable (*node*) has or does not have connections (*edges*) with any other variable. The strength and sign of the connection is reflected by the edge *width* and *color*. The network evaluates how two factors relate to each other while the influence of the others is removed,

[1] The use of the term 'mediation' refers to indirect rather than direct associations between variables (it does not, therefore, imply a causal link).

showing as a result direct and mediated relations between variables. Next, the partial correlation network is regularized using the *EBICglasso algorithm* and setting the *gamma hyper-parameter* at .5[2]. These recommended settings are conservative and favor specificity (the need to identify truly relevant connections) over sensitivity (the interest in detecting any connection), overall reducing the possibility of false positives by shrinking to zero associations that are very small, likely spurious. The additional inclusion of a *threshold* in the network excludes near-zero edges from successive estimates, further eliminating noise related to minor associations. To facilitate network inspection, only statistically significant edge values were displayed, colorblind-friendly edges were used for positive/ negative associations, and maximum edge size was set to the largest observed connection (maximum = .65). Moreover, a *Fruchterman-Reingold layout* was chosen, so that nodes with more/stronger connections appear closer together than those with less/weaker connections (Fruchterman & Reingold, 1991), visually suggesting how variables/nodes are grouped.

Node importance. After network construction, several indices (*centrality measures*) describe the role of each node within the network. A node *strength* sums all weights (absolute values) of the edges that emerge from that node, so a node high in strength has large, direct connections with other nodes; *closeness* refers to the inverse of the sum of the distances of that node from other nodes (its nearness), so a node high in closeness will affect and be affected by more connections, both direct and indirect;

[2] The EBICglasso algorithm minimizes the Extended Bayesian Information Criterion (Foygel & Drton, 2010) and uses the graphical Least Absolute Shrinkage and Selection Operator (Tibshirani, 1996).

finally, *betweenness* is a 'measure of the centrality of a node in a network, and is normally calculated as the fraction of shortest paths between node pairs that pass through the node of interest' (Newman, 2005), so whether it serves as link to several other nodes.

Network accuracy and stability. There is no consensus on a unique way to assess a network goodness of fit (Epskamp et al., 2018). Hence, several tests were carried out with the *bootnet* package to assess whether the network is accurate and stable. A first, general test varies the *gamma hyper-parameter* between 0 (highest sensitivity) and .50 (highest specificity), later adding the threshold parameter, to overview the number of detected/omitted edges as a result. Subsequently, because LASSO regularizations favor specificity over sensitivity, sample size estimations (i.e., power analysis) are pivotal to maximize sensitivity and reduce false negatives. Thus, a further test rebuilds the network using a subsample (n = 50) to check if the network structure is still respected. Next, because EBICglasso regularizations tend to bias data toward zero (Epskamp & Fried, 2018), a *true network* is estimated without the EBICglasso algorithm to test whether the data are better refitted. Afterward, the true network is used within a simulation study that generates samples of increasing size (n = 100, 250, 500, 1000, 2500) applying the actual network features (ordinal variables with up to 7 levels, EBICglasso regularizations, and gamma hyper-parameter set at .5). The generated datasets are used to estimate the sample sizes that are necessary to achieve certain correlations between the centrality measures of the true and estimated network –correlation, sensitivity, specificity, strength, closeness, and betweenness–, overall revealing the reliability of the network features given its actual sample size.

Finally, bootstrapping techniques estimate the accuracy of edge-weights and the stability of centrality measures (Epskamp et al., 2018). To estimate the accuracy of

the edges included in the network, *non-parametric bootstrapping* (i.e., performing resampling with replacement) creates new plausible datasets to estimate confidence intervals around the edge-weights. Non-parametric bootstrapping allows to assess the accuracy of centrality indices and of each edge presence, sign, and strength. Lastly, to estimate the stability of centrality measures, *parametric bootstrapping* (i.e., performing case-dropping without replacement) investigates the correlations between centrality measures of the sample network and centrality measures of the bootstrapped subsets. In particular, the CS/Correlation Stability-coefficient identifies the largest proportion of cases that can be dropped while there is still a large correlation ($\geq .7$, as per Cohen, 1977) with a 95% probability between the estimated centrality indices and the centrality indices after randomly dropping subsets of data. CS-coefficients larger than .5 are recommended, CS-coefficients between .25 and .5 are acceptable, whereas centrality measures are considered unstable and inaccurate with CS-coefficients below .25. We used reliability as the main criteria to decide which particular instantiation of the network to report hereby (see details below), but provided interested readers with supplementary raw data and analysis scripts to rerun the same analyses using the alternative instantiations.

3. RESULTS

3.1. Descriptive statistics and data reduction.

Orthographic accuracy scores (0-1) were on average .73 (SD = .14; range .35 - 1.0). Descriptive statistics of un-scaled items are reported in Table S1. Ninety-three participants failed to respond to the item on last year grades. Excluding these participants from the sample resulted in networks that did not reach threshold

reliability in all criteria (CS-coefficients). Thus, we decided to drop the grades item and build the networks using the larger sample.

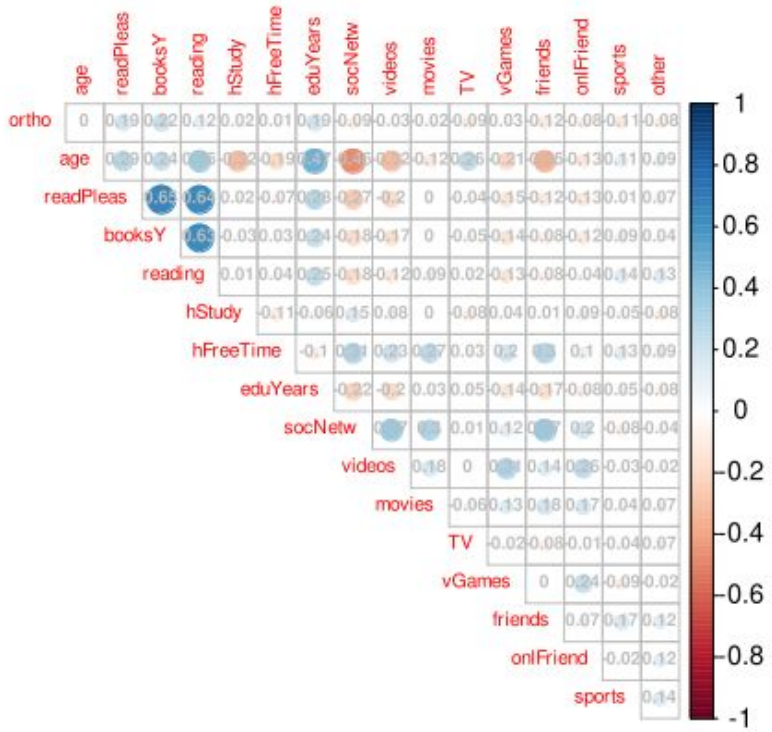
The amount of time that participants spent in diverse activities showed substantial intercorrelations (> .50) during the academic year workdays and weekends and during the holidays (excluding 'seeing friends' during the academic year that was only moderately related, .32, to during the holidays). Free time activities were therefore averaged together and examined with no regard to the part of the week or the year. The resulting network passed the reliability criteria imposed on CS-coefficients.

The three reading enjoyment measures (subjective reading pleasure on a 1-4 Likert scale, number of books read per year, and hours of reading during free time) also strongly intercorrelated (>.63). However, averaging them into a single measure (or grouping them into two measures in the two possible ways) resulted in networks that did not pass our stringent reliability criteria established on CS-coefficients. The only network that passed the reliability criteria included the three measures independently. This is the network that we report in the present paper. However, the supplementary analysis script includes commands to build these alternative networks. Importantly, all alternative networks led to conclusions that fully agree with the conclusions based on the network reported here, further attesting to the robustness of the observed patterns.

Figure 2 shows the matrix of bivariate partial correlation coefficients comprising the variables under scrutiny. Orthography, overall, had weak relations with the other variables (range in absolute value .01 - .22): it improved with reading pleasure, the number of books read per year, and the hours devoted to reading during free time; moreover, orthography increased with greater educational level. It also had small negative correlations with using social networks, spending time watching TV, seeing friends in person or online, and doing sports or other activities. In general, age held

the stronger relations with education, reading habits, and online and in person activities: older participants enjoyed reading and read more, had more years of formal education, and watched more TV; younger participants spent more time studying and at leisure, used online social networks more, watched more short videos and played more video games, but also met more often with friends, both in person and online.

Figure 2. Matrix of bivariate partial correlations using Spearman rho coefficients.



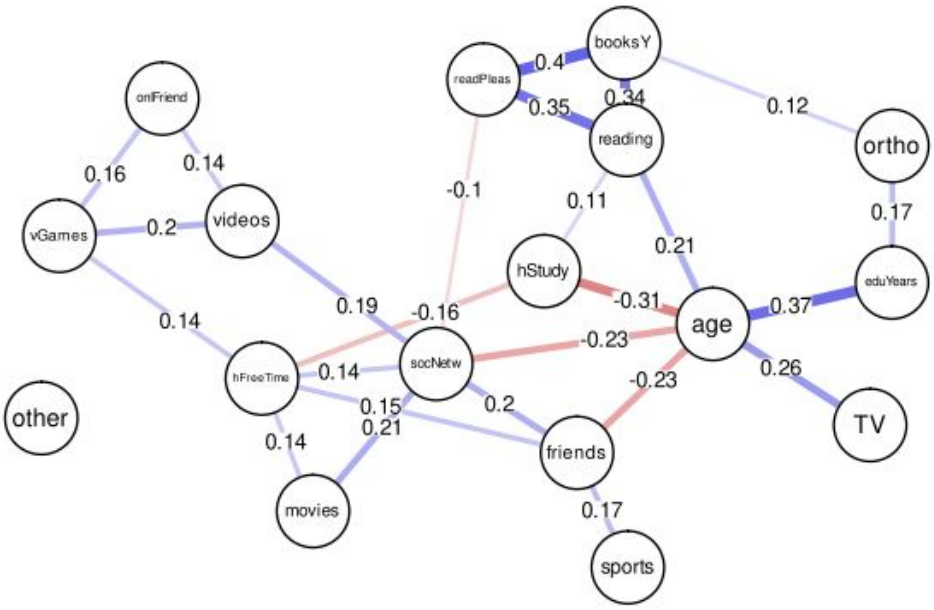
In the matrix of bivariate partial correlations, dots of increasing size and shade indicate stronger positive (blue) or negative partial correlations (red). Values indicate partial correlation coefficients.

Node labels: orthogr = orthography, age = age, readPleas = reading pleasure, hStudy = hours of studying, hFreeTime = hours of free time, eduYears = years of education, reading = time devoted to reading, socNetw = time dedicated to social network, videos = time watching short videos online, movies = time watching movies or series online, TV = time watching TV, vGames = time playing videogames, friend = time to meet friends in person, onlFriends = time to meet friends online, sports = time to do sports, other = time for other activities.

3.2. Network structure.

Figure 3 shows the partial correlation network built with EBIC glasso regularizations, setting γ at .5, and including a threshold. As a result of prioritizing specificity over sensitivity, the network structure was sparse: with 17 variables (nodes) under scrutiny, there were 25 nonzero edges out of 136 possible ones. The edge weights ranged between .1 and .4 (absolute values). The strongest edges were between the three measures of reading enjoyment (time devoted to reading, reading pleasure and number of books read per year, ranging between .34 and .4) and between age and, unsurprisingly, having more years of formal education (.37).

Figure 3. Partial correlation network using EBIC glasso regularization.



Partial correlation network built by applying EBIC glasso regularizations, γ at .5, and a threshold. Among all possible nodes (n = 17), only edges exceeding the threshold (n = 22) are shown. Using a Fruchterman-Reingold layout, nodes with more/stronger connections are placed closer than nodes with less/weaker associations. Edge color indicates positive (blue) or negative (red) associations; edge size is set to the largest observed connection (maximum = .65).

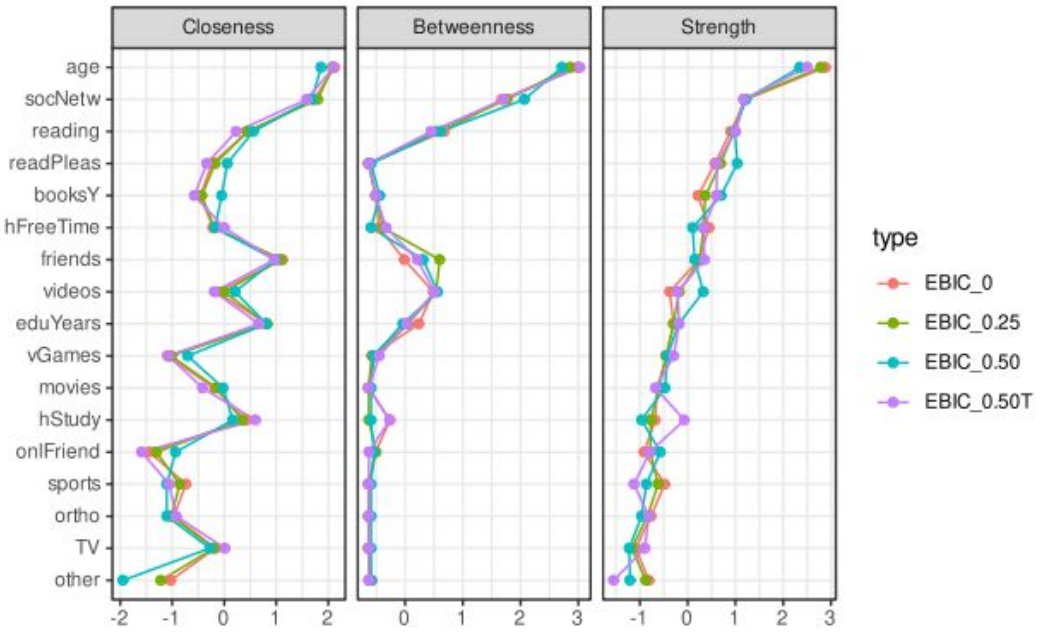
Node labels: orthogr = orthography, age = age, readPleas = reading pleasure, hStudy = hours of studying, hFreeTime = hours of free time, eduYears = years of education, reading = time devoted to reading, socNetw = time dedicated to social networks, videos = time watching short videos online, movies = time watching movies or series online, TV = time watching TV, vGames = time playing videogames, friend = time to meet friends in person, onlFriends = time to meet friends online, sports = time to do sports, other = time for other activities.

Age was a central node in the network structure, as it was strongly related to participants' use of time. Positive blue edges indicate that older participants watched more TV (.26) and read more (.21). On the contrary, negative red edges indicate that younger participants spent more hours studying (-.31), spent more time with friends in person (-.23), and also had a greater use of online social networks (-.23). Social network use was positively linked with reporting more free time (.14) and with sociable activities like meeting more often with friends in person (.2), itself associated with doing more sports (.17). The greater use of online social networks was also linked with more individual activities like watching more movies (.21) and short videos online (.19), the latter associated with playing more video games (.2), and meeting friends online (.14). It is interesting that there is a negative direct link, although weak (-.1), between social networks use and reading enjoyment.

As for the correct use of orthography, the focus of the present study, it increased with the years of formal education (.17). Orthography scores also improved with the number of books per year read for pleasure, itself strongly connected to the other two reading enjoyment measures (as mentioned above). There was not a direct relation between orthography scores and any kind of digital media use. The relation was mediated by other factors, chiefly education and reading habits, which connected orthography with age, which in turn connected to digital media use.

Node importance. Figure 4 (EBIC0.50T) shows the centrality indices ordered by strength, providing an overview of the role of each variable/node within the estimated network. Age and use of social networks were the most relevant nodes, scoring the highest in strength, betweenness, and closeness, followed by time devoted to reading, and reading pleasure. The nodes contributing the least to the network structure were the time spent watching TV, and the time spent in unspecified (i.e., 'other') free time activities.

Figure 4. Node importance.



For each node, centrality indices of closeness, betweenness, and strength are provided. The nodes are ranked based on their strength within the networks built by applying different EBIC glasso tunings (i.e., variations of the γ/gamma hyper-parameter to reach maximum sensitivity, from γ = 0 for maximum specificity to γ = .5 plus threshold for maximum specificity). The network with maximum specificity (EBIC0.50T) is the one shown in Figure 3.

3.3. Network accuracy and stability.

All recommended assessments (Epskamp et al., 2018) support the accuracy and stability of the network. Rebuilding the network with different values of the γ parameter (from 0 to .5), without and with a threshold (Figure S1a-d), produced similar orderings of centrality indices (see Figure 4). Selecting a subsample of 50 participants rendered a network that failed to detect many of the edges of the full sample network, but those that were found respected its structure (Figure S2a-b). The building of the true network and simulations using different sample sizes showed that the actual sample size was enough to achieve high correlations between the centrality measures of the true and estimated network (Figure S3a-b). Finally, non-parametric bootstrapping identified bootstrapped CIs around the edges that were not wide and therefore supported the accuracy of the estimated edges and of centrality indices (Figure S4a-c). Parametric bootstrapping also estimated CS-coefficients. For all centrality indices, CS-coefficients overcame the recommended minimum threshold of .25, revealing the stability of the edges (*CS*(cor = .7) > .75), node strength (*CS*(cor = .7) > .75), betweenness (*CS*(cor = .7) > .75), and closeness (*CS*(cor = .7) > .28), overall supporting the suitability of the sample size and the reliability of the findings.

4. DISCUSSION

Network analyses allowed a multidimensional view of the complex interplay between writing proficiency, as indexed by accuracy in detecting orthographic errors, and the free time devoted to diverse online and offline activities, while also assessing age, education, and reading enjoyment. Free time activities showed a clear relation with age: older participants reported more often reading and watching TV, whereas younger respondents used more frequently social networks. Greater use of social networks was positively related to solitary use of free time (watching short videoclips,

movies, and playing video games), but those digital activities were also related with meeting more with friends online and social media use had a direct relation with spending more time with friends in person (in turn connected with doing more sports). Regarding the focus of the present research, orthography scores increased with greater number of completed years of education and also when participants read more books per year, which in turn was strongly linked to greater liking of reading and spending more leisure time reading. Based on our sample, orthography had no direct association with digital media use. Instead, the relation was mediated by education, reading habits, and age.

The observed lack of a direct relation between written language skills and digital media use among individuals with higher education levels is in line with Rosen et al. (2010), who found that greater frequency of textisms was related to poorer written language skills only among the less educated, whereas among the highly educated grammar scores were substantially unaffected by the repeated use of deviations from standard language. Indeed, it has been suggested that individuals with higher education levels might switch effectively between formal and informal language as they would do with a second language, using both adequately as a function of the context (Jaffe et al., 2012; Verheijen & Spooren, 2021). The present sample was highly educated (86.7% had or were involved in college-level education) and its orthography proficiency varied directly with reading habits and education, which in turn connected to age, which showed clear links to digital media use. This is in line with prior research showing that basic skills like orthography strengthen with extended exposure to texts, increased vocabulary, and wide general knowledge (Hirsch, 2003; Hulslander et al., 2010; Nagy et al., 2022) independently of whether they are achieved through reading for pleasure or through explicit instruction. When

the levels of education are high, the frequency of digital media use may become secondary to the solid written language skills acquired through reading enjoyment and/or formal education.

Orthographic proficiency has strong social correlates as poorer language skills are associated with greater social barriers and struggle in life (Dugdale & Clark, 2008; Pape et al., 2011; Parsons & Bynner, 2007; Pasqualotto et al., 2022). Rather than simply revealing that digital media do not hold a direct relation with written language proficiency, the current findings are in line with previous research demonstrating that explicit education provides an independent route to solid linguistic skills, on a par with reading enjoyment (Hirsch, 2003; Hulslander et al., 2010; Krashen, 2020; Nagy et al., 2022; West & Stanovich, 1991). This leaves open the possibility that the network of associations between social media use and orthography might be structurally different in a less educated sample.

In the present study, network analyses identified that reading enjoyment and formal education are independently associated with written language skills. Indeed, reading at leisure has strong social implications that have been hypothesized to overcome rather than reinforce social inequities (Boonaree, 2015; Dewan, 2016). Reading enjoyment has been found to incidentally supply the widening of knowledge and vocabulary (Krashen, 2020; West & Stanovich, 1991) that substantially contributes to language proficiency (Hirsch, 2003; Hulslander et al., 2010; Nagy et al., 2022). Present data suggest that reading enjoyment also supplies better orthographic skills, thus providing a command of the linguistic norms that constitute a social barrier to the less educated (Carneiro & Gordon, 2013; Pape et al., 2011), helping being identified as an educated person (Jaffe et al., 2012; Parsons & Bynner, 2007; Pasqualotto et al., 2022). Thus, present data support the idea of using promotion of reading programs

and the free and universal access to libraries as a strategy to induce social change (Boonaree, 2015; Krashen et al., 2012; A. M. Ramos & Vila, 2015; F. Ramos & Krashen, 1998).

Present data also uncovered a direct, negative connection between reading pleasure and use of social networks, which are both central nodes in the subnetworks of reading habits and digital media use. Although the negative relation was small, it may hint at opposed attitudes underlying reading pleasure and digital media use. If the relation that is observed in the current sample mirrors dynamic social trends, we can speculate that factors that increase one tendency could be related to decreases in the other. Thus, the raising popularity of digital media use may be associated to less positive attitudes toward reading, but also promoting reading might be associated to less positive attitudes toward digital media use in free time. However, regarding how this balance affects linguistic skills, it is important to keep in mind that present data suggest that formal education provides an independent route for their acquisition.

Concerning the role of digital media in the participants' use of free time, and consistently with prior research (Thurlow, 2006), the network analysis pointed out that those who dedicate more free time to social media reported more solitary activities (watching more short videos and movies online, playing more video games). However, those participants also reported more sociable recreations (seeing friends online and in person more often, the latter associated with doing more sports). Research on how digital media have affected people's lives tends to give a pessimistic view, eventually polarized and exaggerated by the press (Thurlow, 2006). For example, Vilhelmson et al., (2018), examining the Swedish Time Use Survey in 1991, 2001, and 2011, observed an overall decrease in offline social activities, in magazines and books reading, and, generally, in offline hobbies. Researchers additionally found

a decrease in social gatherings ('togetherness') among the elderly (Thulin, 2022), and frequent social media use was associated to increased feelings of loneliness, both among the young and the elderly (O'Day & Heimberg, 2021; Thulin et al., 2022; Twenge et al., 2019). The present findings, together with recent data on the behavioral, social, psychological, and health correlates of social media use, offer instead a more nuanced picture, hinting at simultaneous costs and benefits of digital media use: Thulin and colleagues (2020) found that in the general population the 'pervasive and permanent presence of friends', yet mediated by social media use, is accompanied by a decrease in offline social activities, overall suggesting a decrease of face-to-face 'togetherness' with greater social media use. Further data, however, indicate the opposite pattern: An increase in physical activity, itself linked to more positive affect, among older adults reporting greater social media use (Yao Lin & Lachman, 2021) and, among the younger, the association with stronger feelings of social support (Boer et al., 2020), overall hinting, here, at the social benefits of digital media use. Likewise, against the mainstream narrative (Thurlow, 2006) that refers to the young as "digital natives" and assumes that they make a ubiquitous use of social media, Thulin & Vilhelmson (2019) reported that youth is associated with a heterogeneous use of time as a function of social media use. Accumulating evidence in multivariate designs like the current one, capable of examining large sets of data and complex relations between variables, appears to offer a less black-and-white view on the role of digital media in our daily lives and a more nuanced perspective that will be especially informative when applied to specific subgroups of people.

Within this context, a factor that could shed light on mechanisms facilitating digital media use but that currently does not receive sufficient attention concerns the fact that digital media, being created for profit, do encourage addictive behaviors to induce its

own repeated use . In the search for a more balanced view on digital media presence in our lives, in future studies it might be methodologically and theoretically important to bear its addictive nature in mind (for example, by measuring addiction tendencies as a mediating factor in digital media day-to-day use).

Three are the main limitations of the present work. Firstly, as mentioned above, this is an exploratory study which findings should be tested in confirmatory designs. Secondly, most of the sample consisted of highly educated participants, either studying or having finished a university degree. Therefore, the network structure might be different in a less educated sample, perhaps showing a direct relation between digital media use and orthography. Thirdly, the data were collected at a peculiar social moment, due to the Covid19 pandemic, that may have affected the use of free time in ways that are difficult to estimate. By the time of data collection (April-June 2021), Spain was not in a period of confinement. General confinement in Spain occurred between March and June 2020 and, after the summer, university students attended online classes until April 2021. Therefore, during data collection most of our participants were back to their normal activities, although many were probably still experiencing less face-to-face contacts than before the pandemic. We can speculate that this might have subtracted a constant time from in-person social activities and added a constant time to other options, without changing the relative positioning of the participants. However, this is an empirical question and future work is necessary to provide a definitive answer.

Summing up, in this exploratory study network analyses showed that, among the highly educated, basic written language skills are not directly related to the amount of free time devoted to online activities. Orthographic accuracy significantly increases with years of education, thereby indicating that directed reading and writing activities

provide an effective foundation for basic language skills. Orthographic skills are additionally positively associated with reading enjoyment, further supporting the notion (Mol & Bus, 2011) that reading as a leisure activity boosts incidental language learning. As additional findings, present results also show that reading enjoyment and digital media use held a weak negative relation, and that leisure time activities depend heavily on age: younger people devote more time to digital media, while older people prefer reading and watching TV. Consistent with the contemporary literature cited above, especially the works by Thulin and colleagues, greater social media use tends to be accompanied by more solitary activities (watching more short videos and movies online, playing more video games) but, against some intuitions, it is also linked to more online and offline social contact (seeing friends in person, which is in turn linked to doing more sports). Taken as a whole, present and previous data do not allow a black-and-white view of digital media influence in our daily lives, suggesting the need of a more nuanced understanding of digital media use costs and benefits.

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