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Gender, Technology Use, and Deductive Reasoning: An Empirical Study From a Spanish Speakers Sample

Género, Uso de la Tecnología y Razonamiento Deductivo: Un Estudio Empírico con una Muestra Hispanohablante

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Based on the extended mind perspective (i.e., the notion that the human mind is a bodily process extended and distributed throughout the environment), it is argued that human cognition is impacted by digital technologies. However, little is known about how technology links to deductive reasoning skills and to what extent, if any, a technology-plus-mind synergy may alter higher cognition. Since men and women differ in their purposes for using technological devices, the research aimed to detect whether gender patterns of technology-based behaviors may be associated with differences in deductive reasoning skills. To this end, data from 222 participants was collected mainly through social media networks. A total of 68% of the sample informed having coursed higher education studies from different Spanish universities. A Questionnaire in Technology Use was developed, including three dimensions (i.e. digital devices and their frequency of daily use, technology-based activities, and digital contents). Deductive reasoning was assessed through classical tasks (i.e. the THOG problem, the Wason´s Selection Card and a set of syllogisms). Correlations, t tests for independent samples, and two-way ANOVAs were performed. The results revealed: (a) gender patterns in technology use: men were prone to recreational activities and women were more learning-oriented and preferred topics related to self-projection and (b) a link between gender patterns of technology usage and deductive reasoning: in women a positive but mild association was found between technology use and performance on reasoning tasks. These preliminary results challenge the notion of higher cognitive offloading on technology, especially in women, and suggest a gender gap in the nexus between technology-based behaviors and deductive reasoning skills.

Keywords: technology use, smartphones, deductive reasoning, extended mind, gender differences

De acuerdo con la teoría de la mente extendida, a partir de la cual la mente se entiende como un proceso corporeizado, extendido y distribuido por el entorno que rodea al individuo, se afirma que las tecnologías digitales impactan en la cognición humana. Sin embargo, aún se desconoce cómo se relaciona el uso de la tecnología con procesos cognitivos superiores como el razonamiento deductivo. Dado que hombres y mujeres difieren en sus intereses a la hora de usar dispositivos tecnológicos, este trabajo tuvo por objetivo identificar patrones de género en el uso de la tecnología y determinar en qué medida se asocian con diferencias a la hora de resolver tareas de razonamiento deductivo. Para ello, se realizó un estudio empírico compuesto por 222 participantes, localizados en su mayoría a través de redes sociales, de los cuales el 68% informó haber cursado estudios superiores en diferentes universidades españolas. Se desarrolló un Cuestionario sobre Uso de la Tecnología, compuesto por tres dimensiones (i.e. dispositivos digitales y frecuencia de uso diario; actividades mediadas por la tecnología, y contenidos digitales). Para evaluar el razonamiento deductivo se utilizaron tareas clásicas (i.e. el problema del THOG, la Tarea de Selección de Cartas de Wason y un conjunto de silogismos). Se aplicaron correlaciones, pruebas t para muestras independientes y ANOVAs de dos factores. Los resultados revelaron (a) diferencias de género en el uso de la tecnología. Mientras que los hombres utilizaban en mayor medida la tecnología con fines recreativos, las mujeres estaban más orientadas al aprendizaje y preferían temas relacionados con la imagen y (b) se identificaron patrones de género diferenciados en cuanto a la relación entre el uso de la tecnología y la capacidad para resolver tareas de razonamiento deductivo. En particular, en las mujeres se encontró una asociación positiva, aunque leve, entre el uso de la tecnología y el rendimiento en las tareas de razonamiento. Estos resultados preliminares desafían la noción de que la tecnología esté suplantando el pensamiento como forma de liberar recursos cognitivos a la hora de resolver tareas complejas, especialmente en el caso de las mujeres.

Palabras clave: uso de tecnología, teléfonos inteligentes, razonamiento deductivo, mente extendida, diferencias de género

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In 2008, Nicholas Carr published a polemic article entitled "Is Google making us stupid? What the Internet is doing to our brains", in which the author argued that the Web was rewiring his brain neural circuitry due to his massive use of technology. He regretted that he was no longer able to display as much a slow and reflective thinking.

Two years later, Anderson and Rainie (2010) conducted an online survey were 895 technology stakeholders and experts were asked to decide whether they agreed or not with the following statement: "By 2020, people's use of the Internet has enhanced human intelligence; as people are allowed unprecedent access to more information, they become smarter and make better choices. Nicholas Carr was wrong: Google does not make us stupid" (p. 2). Seventy six percent of them agreed with the statement.

Gender issues were not part of the Anderson and Rainie's survey. The authors did not ask whether the Internet was expected to affect men's and women's cognition differently. As gender differences in technology use are widely reported (Goswami & Dutta, 2016; Kimbrough et al., 2013), the question seems to be worth investigating. This work aimed to provide new empirical evidence in this respect from a Spanish-speaking sample.

Technology and the Extended Mind

Little is known about how thinking and reasoning are extended throughout the use of digital technology, the so-called extended mind (EM) hypothesis. EM states that the mind goes beyond the boundaries of the skull and in doing so, it is distributed throughout the environment in which the organism is embedded (Clark & Chalmers, 1998; de Aldama, 2020; Heersmink, 2017; Telakivi, 2023). This is also known as active externalism, since the environment is not a mere context where cognitive process is displayed, but an active element in driving it (Clark & Chalmers, 1998). A common example of EM is remembering phone numbers, which are stored in long-term memory, but are nowadays externalized on smartphones. According to Clark and Chalmers (1998), smartphones meet the three conditions (i.e., reliability, trustworthiness, and easy accessibility) needed to make a specific external resource a proper part of the cognitive system.

In general, digital technologies present multiple features that make them appealing to count as EM. For example, they can process much more information and much faster than humans do. By processing ever-increasing amounts of data, they also help to identify hidden behavioral patterns (Hilbert, 2020), modify the perception of reality (Chalmers, 2022), and change the way the past is recalled (Fisher et al., 2021). However, some authors have warned of the risks for human cognition associated with the continuous use of these technologies (Barr et al., 2015; de Aldama & García-Pérez, 2023). In a review conducted by Wilmer et al. (2017), the authors analyzed the links between smartphone usage habits and cognitive functioning. Though acknowledging a major limitation in many of the studies they reviewed, it was concluded that in general the empirical evidence seems to point towards an inverse relationship between smartphone use and cognitive processes, such as attentional, mnemonic, and executive functioning. Moreover, Barr et al. (2015) suggested that smartphones are being used to supplant thinking. These authors found that those participants who relayed more often on their devices usually displayed lower analytical thinking skills. Further research is needed to confirm this conclusion.

Despite the supporters and detractors of technology, there is a widespread agreement on the fact that technology affects human cognition depending largely on how it is used (Cecutti et al., 2021; Wilmer et al., 2017). Because motivations and interests in using technology differ between men and women, gender differences in digital behavior are key to understanding.

Gender Differences in Digital Behavior

Early studies on Internet adoption and digital behavior were mainly depicted as male-centered (Morahan-Martin, 1998; Wilder et al., 1985). As Weiser (2000) stated, "Many have regarded the Internet as a technological 'boy toy', an electronic pathway to riches of information and entertainment that was developed exclusively by men for men" (p. 168). In those days, around two thirds of Internet users were men and accounted for approximately 77% of online-time (Morahan-Martin, 1998). Men were more likely to use the Internet for dating, looking for job offers, accessing general information and news (especially about sports, finances, and politics) and playing games. In contrast, women were more likely to use it for interpersonal communication, such as emailing and chatting with relatives and friends (Weiser, 2000).

More recently, new tendencies in digital and online behavior have emerged. For instance, Kimbrough et al. (2013) found that women, compared to men, preferred using technology to send text messages, video chat, and browse social media networks to catch up on their relationships. This result is aligned with the findings reported by Muscanell and Guadagno (2012), where women were more likely to use social media to maintain existing relationships, whereas men were more likely to use them to build new ones.

Goswami and Dutta (2016) reported mixed results on gender differences in technology usage. In this review, gender was found to be a significant variable when considering the context of usage of information technology (i.e., computers, email services, electronic data management systems, among others). Men were more adept than women at using information technology. Similar results arose regarding the acceptance of e-learning applications, especially those concerning online stock trading. Yet, gender was not a key factor when considering other uses of technology. For example, the authors found no significant differences in terms of e-commerce and online shopping. Furthermore, interactions via social media were similar between men and women, even though, as previously described (Muscanell & Guadagno, 2012), gender purposes for using social media platforms may differ.

Quite similar results were found in a review (in the period 2000-2017) conducted by Shaouf and Altaqqi (2018). The authors concluded that men were more likely to try new information technologies and generally had more positive evaluations of websites than women, though the results were somehow contradictory. In another review and meta-analysis led by Qazi et al. (2022), a positive, yet not significant, effect size in favor of men was found, in terms of information and communication technology (ICT) use and skills (e.g., self-efficacy). Regarding the adoption and use of emerging technologies, such as virtual reality (VR), men seem to hold a more positive perception than women, though once again literature shows a blended picture. For instance, Cummings et al. (2023) found that gender was a marginally significant predictor of VR device adoption, with female respondents adopting VR devices earlier than their counterparts. Nevertheless, gender was not determinant when comparing performance. Many authors have reported that women are more likely to mention discomfort when using VR devices (i.e., *cybersickness*), though the underlying reasons remain unknown (Grassini & Laumann, 2020; MacArthur et al., 2021; Stanney et al., 2020)

Within the Spanish context, according to the Observatorio Nacional de Tecnología y Sociedad [ONTSI] (2023), women are more prone to use Internet to search for health-related topics, whereas men are more likely to use it for leisure purposes (e.g., playing video games). The same report informs that in 2021, 29.1% of women undertook online courses (regardless of the topic) and 37.5% used online sources for learning. These figures represent 3.8 and 0.4 percentage points more than men, respectively.

Besides these mixed results, it is a major concern that gender differences in technology usage do not only represent differences between men and women in terms of motivations and interests, but also a digital divide. As the Organisation for Economic Co-operation and Development [OECD] (2018) states, "the benefits of the digital transformation are currently not equally balanced between societal groups and genders and access, use and ownership of the digital tools are not gender-neutral" (p. 22). Several reasons may underlie this gap. Importantly, socio-cultural values and norms associated to key differences between men and women may lead to gender-based digital exclusion. For instance, the UN Women's report (2018) claims that women perform 2.6 times the amount of unpaid and domestic work that men do, which, in turn, leaves women less time to develop their careers and professions, including digital literacy skills. Similarly, traditional gender roles (i.e., women being more care-oriented and men being more science-oriented) seem to be an important part of the problem. According to the United Nations Educational, Scientific, and Cultural Organization (2017), women are around four times less likely than men to have advanced ICT skills, such as the ability to program computers.

Due to the fact that women have less chance to develop their digital skills, more negative consequences for women are associated. To illustrate, they are more likely than men to feel more "technophobia" or less self-confidence when using technology (OECD, 2018). This situation becomes even worse when women are uneducated, unemployed or have a low socioeconomic status (Intel & Dalberg, 2014). Another side effect is that women are more likely to be unaware of the potential benefits of using technology, which in turn again provides them fewer chances to develop their digital skills.

These figures are nuanced when considering the Spanish reality. Thus, while some digital gender gaps have been already overcome (frequency of Internet use), others remain unalterable. For example, 62.7% of Spanish women present basic or higher digital competencies, which is three percentage points below men (ONTSI, 2023). Moreover, men perform better than women in three of the five areas of the digital competencies, especially regarding the creation of digital content and solving problems (3.9 and 3.6 percentage points higher in each dimension, respectively).

Sociocultural values and norms (i.e., traditional gender roles) that underlie gender variations in digital skills may also be responsible for gender differences when choosing a professional career. According to OECD (2020), in 2017 women accounted for up to 77% on average of new entrants to health and welfare bachelor's programs within OECD countries, whereas they represented only 30% new entrants to bachelor's programs in Science, Technology, Engineering, and Mathematics (STEM fields). In Spain, only 17.8% of STEM-trained employment are women (ONTSI, 2023)

Because STEM fields promote higher-order thinking skills (e.g., critical thinking, scientific reasoning) and are in high demand, gender differences concerning reasoning skills are reviewed next.

Gender Differences in Reasoning

Reasoning can be understood as the process of drawing inferences (i.e., conclusions) from some initial information (i.e., premises). It has been studied in different contexts as scientific reasoning, pragmatic reasoning, moral reasoning, informal reasoning and so on, and largely investigated under the deductive versus inductive dichotomy (Heit & Rotello, 2010; Rips, 2001; Sloman, 1996). On the one hand, deductive reasoning is a logical approach in which, the premises being true, there is no option for the conclusion to be false. On the other hand, in inductive reasoning the veracity of the premises does not guarantee the veracity of the conclusion, but makes it more plausible (Holyoak & Morrison, 2005).

The literature draws a mixed picture regarding gender differences in both deductive and inductive reasoning. Some authors claim that boys are more prone to reach a conclusion from general ideas (deductive reasoning), whereas girls are better at generalizing from particular observations (inductive reasoning), though not much empirical evidence is provided (Geist & King, 2008; Gurian & Stevens, 2010). A recent meta-analysis (Waschl & Burns, 2020) concluded that men show higher inductive reasoning skills; however, this was a small overall effect and variables such as stimuli and item type may influence the observed difference.

In a type of deductive process such as scientific reasoning, the results are also inconsistent (Luo et al., 2021). Some authors found differences between men and women (Demirtaş, 2011; Luo et al., 2021; Yang, 2004), while others did not (Bezci & Sungur, 2021; Molnár, 2011; Piraksa et al., 2014). In a critical review concerning differences in intrinsic aptitude for mathematics and science, Spelke (2005) reported no systematic evidence to support intrinsic differences between men and women. Instead, the author concluded that talent for mathematics and science develops from a set of biological features shared by both. Furthermore, Hyde (2014) asserts that in general women have reached parity with men in mathematical performance, even in complex problem solving at the high school level. Accordingly, contemporary data largely support the so-called gender similarity hypothesis; that is, men and women are similar in most psychological traits, but not all (Ball et al., 2013; Bosson et al., 2021). In other words, intergroup differences between men and women are smaller than intragroup differences. These results are also consistent with the meta-synthesis conducted by Zell et al. (2015), where the findings provided convincing support for the gender similarity hypothesis. However, not all authors reach the same conclusions and some experts argue that larger gender differences are common in key areas of human functioning (Archer, 2019). Some of these discrepancies could be due to differences in analytical approaches and ways of organizing the same data (Eagly & Revelle, 2022).

Additionally, the OECD's 2018 Programme for International Student Assessment (PISA) showed that in OECD countries boys scored five points higher than girls in mathematics, but the latter scored two points higher than their counterparts in science. In Spain, some differences were found. Thus, boys scored six points higher than girls in mathematics, but both scored similarly in sciences (Instituto Nacional de Evaluación Educativa, 2019). However, systematic evidence regarding Spanish-speaking population is still scarce.

Research Question

Based on the above findings, this work aimed to address the following research question:

Are there gendered patterns of technology-based behaviors associated with differences in deductive reasoning skills? In order to answer this question, gender-based differences in technology usage were first identified in the sample, in terms of characteristics such as digital devices, technology-based activities, as well as content and topics. The sample roughly replicates the general results from the Spanish context in terms of gendered patterns of technology-based behaviors (see Results section and ONTSI, 2023 for a comparison).

Method

Participants

A total of 223 individuals (62.16% women; M_{age} = 30.67, *SD* = 11.51) participated in the study. One person was removed since this person did not accept to sign the informed consent. Therefore, a sample of 222 participants were considered for the analysis. A total of 68% of the sample informed having coursed higher education studies, all of them coming from 26 Spanish universities across 12 cities (two universities were online based). The disciplines covered included STEM, arts, behavioral sciences and health. Fluency in Spanish was required as an inclusion criterion.

Instruments

Questionnaire in Technology Use

To study gender-based differences in technology usage, a questionnaire with three dimensions was developed and implemented, namely, (a) digital devices and their frequency of daily use, measured by a 7-point Likert scale, where 0 = *not having or using the device*, 1 = *less than 1 hour per day*, 2 = *between 1h-2h per day*, 3 = *2h-3h per day*, 4 = *4h-5h per day*, 5 = *5h-6h per day*, and 6 = *6 or more hours per day*; (b) technology-based activities (e.g., navigating through social media, playing video games, creating documents); and (c) digital contents (e.g., technology, science, fashion, politics). Both (b) and (c) were measured using a 5-point Likert scale ranging from 0 = *never* to 4 = *always*.

Reasoning Tasks

Reasoning skills were evaluated by three deductive reasoning tasks: (a) a set of six syllogisms of varying difficulty, a measure of the conflict between logic and beliefs in syllogistic reasoning (Evans et al., 1983); (b) the THOG problem (Wason & Brooks, 1979), a measure of disjunctive reasoning; and (c) The Wason's Selection Card (Wason, 1968), a measure of conditional reasoning. The present work assessed participants' performance in deductive reasoning tasks, since the measurement relies on objective criteria. Finally, a total score for Reasoning Tasks was computed from the scores on each task, assigning one point for each correct item (up to 6 points for syllogisms, up to 4 points in the THOG task, and up to 1 point in the Wason's Selection Card). As a result, each participant was assigned a total reasoning score ranging from 0 to 11, meaning that a higher mark implied a better performance at deductive reasoning See Appendix A. Complementary Materials for a thorough description of these instruments. The data set is available at OSF (https://osf.io/7k534/?view_only=f2dc661ce0af4c059535a1f4a6c5ff87).

Procedure

Participants were recruited using a non-probability sampling, more precisely a non-proportional quota sample (Etikan & Bala, 2017) that allows us a quantitative analysis. The volunteers were contacted during March and April 2020 by the research team assistants mainly through social media networks such as Facebook and Instagram, using personal outlets and online groups of shared interests (i.e. hobbies). Participants individually completed the online surveys through Google Forms after agreeing to sign the informed consent. Data was analyzed using IBM SPSS Statistics v.27 and Jamovi 2.3.21 (Jamovi Project, 2021). The research was approved by the ethics committee of the CES Cardenal Cisneros.

Google Forms was used as the platform to gather the data and were employed to analyze it.

Data Analysis

Descriptive and inferential analyses were done. Assumptions and potential sources of data bias (e.g., missing values and outliers) were checked. Missing values were below 5%, which according to Shaffer (1999) is inconsequential. Little's Missing Completely at Random (MCAR) Test revealed that the missing data in the dataset was likely to be completely at random, χ^2 (42) = 41.643, p = .487. Few outliers were found in the total score of Reasoning Tasks (id 78, 12, 123, 6, and 47 in the lower bound; id 221, 179, 222, and 169 in the upper bound), but they remained as part of the dataset, since they were not due to wrong processing Independent samples t-tests were conducted to assess significant differences between men and women across various dimensions of technology use. Correlation analyses examined linear associations between gender-based technology behaviors and performance in deductive reasoning tasks. Given that smartphones were the most frequently used technology among both men and women, a series of two-way ANOVAs were performed to explore potential interactions between smartphone use and gender in explaining deductive reasoning performance. Eta squared (η2) was used as a measure of the effect size to indicate the proportion of variance of deductive reasoning performance attributed to the independent variables. For multiple comparison tests , the Bonferroni correction was applied to control the family-wise error rate (Lee & Lee, 2018). The jpower module in Jamovi 2.3.21 suggested that an independent samples t-test with n_{m} = 84 and n_{w} = 138 would be sensitive to effects of Cohen's d = 0.4 with 83% power (α = 0.05, two-tailed). This means that effects smaller than Cohen's d = 0.4 would not be reliable detected (Bartlett & Charles, 2022).

Some sociocultural factors that have been shown to influence gender differences in technology were tested. Educational level was gender-balanced, χ^2 (1, n = 219) = 1.074, p = .300 (including three missing values). In both men and women, 63.9 % and 70.6% of the participants, respectively, reported having conducted higher education studies. In terms of fields of knowledge, the sample was biased towards the usual direction (OECD, 2020; ONTSI, 2023): men were more likely to study STEM careers, whereas women were more inclined towards social and health sciences, χ^2 (1, n = 150) = 15.423, p = 0.009, *Phi* (φ) = 0.321 (medium effect). No gender differences in deductive reasoning were found (see Table S1 in Supplementary Data for further details).

Results

The findings show the devices most frequently used by participants were smartphones (M = 3.34, SD = 1.39), computers/laptops (M = 2.91, SD = 2.04), and smart TVs (M = 1.74, SD = 1.23). Emerging technologies such as VR, augmented reality (AR) or extended reality (ER) were hardly used (M = 0.16, SD = 0.57). Participants also reported using digital devices mainly to navigate through social media (M = 3.25, SD = 0.89), searching for information (M = 3.22, SD = 0.74), and watching videos (M = 2.77, SD = 1.12). Finally, the digital contents most frequently searched were breaking news (M = 2.71, SD = 0.94), curiosities (M = 2.32, SD = 1.05), and humorous topics (M = 2.14, SD = 1.18).

When considering gender, distinct patterns emerged between men and women. Regarding digital devices, men used more often video game consoles than their counterparts, whereas women used more frequently smart TVs. The latter result is not statistically significant when the Bonferroni correction is applied. Regarding technology-based activities, men preferred playing videogames and using simulators, in comparison to women, who preferred consulting tutorials to learn (e.g., science, traveling, cooking, carpentry). Finally, as for digital contents, men preferred content related to technology and sports, while women had a higher preference for content related to fashion. In terms of reasoning skills, both men and women performed similarly (M_{men} = 5.47, SD = 1.77; M_{women} = 5.44, SD = 1.66). See Table 1 for means, standard deviations and effect sizes regarding the three largest gender differences in each dimension (digital devices used, technology-based activities conducted, and digital contents consulted).

Table 1

The Three Largest Gender Differences in Digital Devices Used, Technology-based Activities Conducted, and Digital Contents Searched

Technology use	Specific technology	Men		Women		$/M_m$-$M_w/$	$t(220)$	p	d
		M_m	SD	M_w	SD				
Digital devices (0-6)	Video game consoles	1.01	1.331	0.19	0.492	0.82	6.577**	< .001	0.91
	Smart TV	1.49	1.114	1.90	1.275	0.41	2.438	=.008	0.34
	Smart watch	0.82	1.640	0.50	1.310	0.31	1.570	=.069	0.22
Technology-based activities (0-4)	Playing videogames	2.05	1.405	1.28	1.176	0.77	4.403**	< .001	0.61
	Tutorial consulting	2.08	1.078	2.54	1.026	0.46	3.179*	<.001	0.44
	Using simulators	0.60	1.173	0.19	0.586	0.41	3.433**	< .001	0.47
Digital contents (0-4)	Fashion	1.02	1.097	1.88	1.211	0.86	5.271**	< .001	0.74
	Technology	2.38	1.191	1.76	1.022	0.62	4.114**	< .001	0.56
	Sports	2.13	1.249	1.55	1.239	0.58	3.374**	< .001	0.47

* The Bonferroni correction ($\alpha = 0.05$) = α / k (number of hypotheses tested) = 0.05 / 3; Adjusted $\alpha = 0.02$; $p < 0.02$
**The Bonferroni correction ($\alpha = 0.01$) = α / k (number of hypotheses tested) = 0.01/3; Adjusted $\alpha = 0.003$; $p < 0.003$
M = Mean; *SD*: Standard deviation; $/M_m$-$M_w/$ = Absolute value of the means' differences.

When looking at significant links between the dimensions of technology usage and reasoning skills, distinct patterns between men and women were also detected. In general, there was a mild positive association between technology usage and reasoning tasks' performance in women, whereas there was no clear connection in men. Specifically, women presented a small positive correlation between the total reasoning score and smartphone use ($p < .001$), computer/laptop use ($p < .001$), keeping updated ($p = .011$), simulator use ($p =.019$), searching for breaking news ($p < .001$) and politics ($p = .007$). See Table 2 for details.

Table 2

The Top Three Largest Gender Differences in Pearson's Correlations Within Each Dimension of Technology Usage and Total Reasoning Score

Technology use	Specific technology	Total reasoning score (0-11)						$/r_w$-$r_m/$
		Men			Women			
		M	SD	r_m	M	SD	r_w	
		5.47	1.77		5.44	1.66		
Top three digital devices	Computer/laptop			0.019			0.283**	0.264
	Smartphone			0.093			0.342**	0.249
	e-book			-0.088			0.115	0.203
Top three technology-based activities	Video conferences			-0.197			0.134	0.331
	Keep updated			-0.087			0.216*	0.303
	Use simulators			-0.074			0.199*	0.273
Top three digital contents	Breaking news			0.040			0.297**	0.257
	Politics			0.043			0.228**	0.185
	Humor			0.151			-0.012	0.163

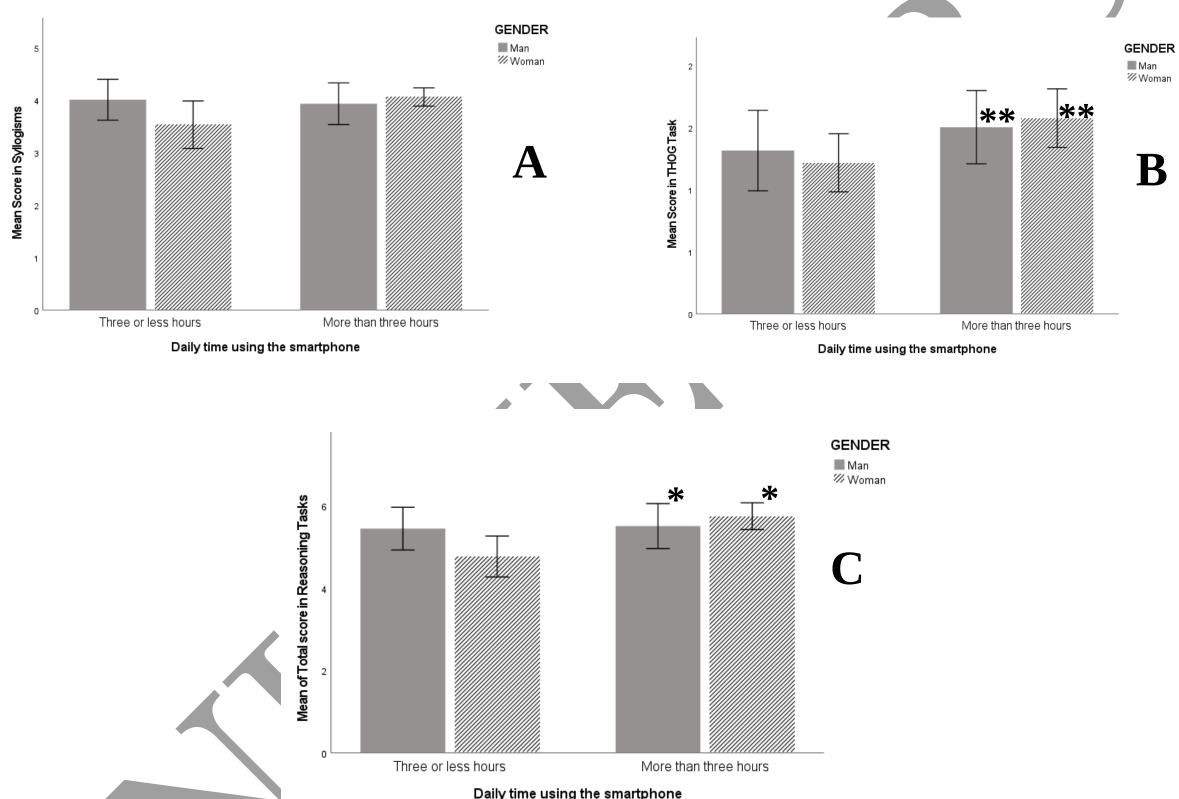
* The Bonferroni correction ($\alpha = 0.05$) = α / k (number of hypotheses tested) = 0.05 / 3; Adjusted $\alpha = 0.02$; $p < 0.02$
** The Bonferroni correction ($\alpha = 0.01$) = α / k (number of hypotheses tested) = 0.01 / 3; Adjusted $\alpha = 0.003$; $p < 0.003$
M = Mean; *SD*: Standard deviation; $/r_w$-$r_m/$ = Absolute value of the correlation's differences.

First, for syllogism solving, a marginally significant interaction between gender and smartphone usage was found, $F(1, 218) = 3.724$, $p = 0.055$, $\eta^2 = 0.017$ (mild effect). Women with higher smartphone use ($M = 4.10$, $SD = 0.80$) were more likely to score higher in syllogistic reasoning than women with lower use ($M = 3.73$, $SD = 1.25$). This pattern was inverted for men, as smartphone use was associated with lower scores in this type of reasoning ($M = 3.79$, $SD = 1.65$ and $M = 4.06$, $SD = 1.00$, for higher and lower use, respectively). See Panel A in Figure 1.

Second, for THOG problem solving, the ANOVA analysis revealed a significant main effect of smartphone usage, $F(1, 218) = 7.386$, $p = .007$, $\eta^2 = 0.033$ (mild-moderate effect). Both men and women with higher smartphone use ($M_M = 1.62$, $SD = 1.10$; $M_W = 1.73$, $SD = 1.19$, respectively) were more likely to score higher in disjunctive reasoning than their counterparts ($M = 1.30$, $SD = 0.91$; $M = 1.27$, $SD = 0.92$, respectively). See Panel B in Figure 1. No other significant effects were found.

Figure 1

Mean Reasoning Scores as a Function of Gender and Daily Time Spent Using Smartphones.



Note: Panel A: Interaction in a two-way ANOVA between gender (men, women) and daily time spent using the smartphone (less than 3h, more than 3h) on the resolution of syllogisms. Panel B: Main effect of daily time spent using the smartphone (less than 3h, more than 3h) in a two-way ANOVA on the resolution of THOG problem. Panel C: Main effect of daily time spent using the smartphone (less than 3h, more than 3h) in a two-way ANOVA on the total score in Reasoning Tasks. Error bars: 95% CI. *$p < 0.05$, ** $p < 0.01$

Third, a significant main effect was found between smartphone usage and total reasoning score, $F(1, 218) = 4.152$, $p = .043$, $\eta^2 = 0.019$ (mild effect). See Panel C in Figure 1. Notably, the interaction between gender and smartphone usage was close to statistical significance, $F(1, 218) = 3.486$, $p = .06$, $\eta^2 = 0.016$. The results indicated that women with higher smartphone use ($M = 5.97$, $SD = 1.56$) tended to score higher on general reasoning skills than women with lower smartphone use ($M = 5.05$, $SD = 1.62$). In contrast, men's reasoning skills were independent of smartphone use ($M = 5.50$, $SD = 2.18$ and $M = 5.46$, $SD = 1.44$, for higher and lower use of smartphone, respectively). Additionally, for the Wason Selection Card solving, less than 10% of the sample got the correct answer, which suggests a floor effect.

Finally, a three-way ANOVA was conducted to determine whether the association between the use of smartphones and performance in deductive reasoning tasks was moderated by the educational level or not. A significant main effect was found between educational level and total reasoning score, $F(1, 211) = 5.634$, $p = .022$, $\eta^2 = 0.025$ (mild effect). In particular, participants with higher education performed better in solving reasoning tasks ($M = 5.70$, $SD = 0.14$) than participants without higher education ($M = 5.09$, $SD = 0.22$). However, no interaction was found between educational level, gender, and smartphone usage, $F(1, 211) = 0.103$, $p = .106$. (see Figure S2 in Supplementary Data for further details).

Discussion

The findings provide new insights concerning gendered patterns of technology-based behaviors and their relationship with deductive reasoning skills.

To begin with, previous studies on men and women's use of digital technologies we partially replicated. Generally, participants reported that emerging technologies (i.e., VR, AR, or ER were not yet fully integrated into their everyday lives. The potential impact of these technologies over cognitive systems remains unclear but is expected to be more prominent in the future. Consistent results were also found on social media engagement using smartphones as the most common technology-based activity (Kemp, 2020; StatCounter, 2024).

Furthermore, the most searched digital contents were those related to breaking news, curiosities, and humor, since people are usually interested in keeping updated with the latest events (Google Trends, 2021).

When considering the use of technology by gender, the activities and the targeted contents differed. As in previous studies (see, for instance, Kimbrough et al., 2013), women showed interest in technology as a means of social connection, allocated greater attentional resources to topics related to self-projection (e.g., fashion.), and were more willing to use technology as a learning tool (e.g., consulting tutorials for learning). In contrast, men were prone to use technology for recreational purposes (e.g., using video game consoles and watching videos; see, for example, Goswami & Dutta, 2016). These results are consistent with those of previous studies, aligned both with international trends (OECD, 2018) and particularly in the Spanish context (ONTSI, 2023).

Gender differences in the use of digital technologies were not extended to reasoning skills. Men and women performed similarly, despite the sample being, as the general population, unbalanced in terms of the studies conducted by the respondents. Women reported more often to undertake studies associated with health and social sciences, whereas men informed more frequently to pursue STEM careers. This is aligned with the evidence that women achieve parity with men in solving complex problems, also known as the similarity hypothesis (Bosson et al., 2021; Hyde, 2014; Zell et al., 2015). However, unique patterns were revealed in men and women regarding the relationship between technology use and solving reasoning tasks. Women showed a positive association between the use of digital devices, such as smartphones and computers/laptops, and the resolution of reasoning tasks, with a mild to medium effect. This is in contradiction with the results of Barr et al.' (2015) research, in which heavier smartphones users, regardless of gender, performed worse in solving reasoning tasks than those whose smartphone usage was softer. The authors interpreted these results as evidence that people were using smartphones to offload their thinking.

According to the OECD (2018), one of the reasons why fewer women than men use digital tools is the lack of awareness of the potential benefits that technology might bring. In the present study, women who displayed greater smartphones use may do so because they were aware of the potential benefits. This would be consistent with the fact they were more likely to score higher on reasoning tasks. Better reasoning might help identify the benefits and disadvantages of technology. In particular, it might help acquire digital skills which, in turn, provide more chances of success in current highly technological societies. The acquisition of these skills requires much time of practice and experience.

In the case of men, it could be argued they did not need so much awareness of the potential benefits to make a massive use of technology. Traditionally, technology has been designed mainly by men and for men. As West et al. (2019) crudely states:

> In a pessimistic analysis, women enter technology domains only after their parameters and norms have been established by men. Alternately, women are quickly displaced by male decision-makers and technical workers as norms are set. This is not to say that women and society will not have opportunities to rewrite these norms, but this takes time and requires more effort than simply setting standards and expectations from the beginning (p. 101).

Evidence seems to support this statement. According to the OECD (2018), the proportion of female ICT specialists in G20 countries ranged from 13% to 32%. The same report informs that women obtained only 7% of ICT patents in G20 countries and founded only 10% of technology start-up companies. Besides, the percentage of technical employees who are women tends to be underrepresented. According to Ritcher (2021) the figures for some of the "tech giants" are not very encouraging: only 24% at Apple, 25% at Google, and 23 % at Microsoft are women with highly technical skills. This evidence is consistent with the fact that currently the gender digital gap regarding the access to technology (i.e., the first gender digital divide) is not a major concern, at least not in most OECD countries, and in Spain in particular (ONTSI, 2023), but still there is a large digital gap (i.e., the second gender digital divide) that refers to highly technical skills (Martínez-Cantos, 2017; OECD, 2019; Tyers-Chowdhury & Binder, 2021; West et al., 2019). In Spain, this could be related to the fact that men outperform women in problem-solving through digital tools (ONTSI, 2023). These findings seem to indicate that technology and the mind are differently coupled depending on gender.

In addition, men seem to be more willing to explore the possibilities of emerging technologies, such as VR, AR, or digital simulations. Historically, men have adopted technology earlier than women (Weiser, 2000). For this reason, it is plausible that men benefit more from the positive cognitive outcomes associated with the use of these emerging technologies, but also suffer the potential negative consequences (e.g., "cybersickness" associated to game playing; see, for instance, Lavoie et al., 2021). Furthermore, women report discomfort when using VR devices more often than men. Some authors have tried to explain this by referring to differences in hormonal levels (Clemes & Howarth, 2005) or sexual dimorphism (Munafo et al., 2017), but no consensus has been reached yet.

The present study found no evidence that technology use per se causes thinking enhancement or diminishing. Considering smartphone use, men performed equally on reasoning tasks, independently of their use. This means that technology use itself is not a sufficient condition to favor one or another. On the contrary, technology is more likely to be used for more pragmatic or epistemic goals and purposes (de Aldama & Pozo, 2020), thus reinforcing the previous disposition. As Ellis states, "stronger intellects will use Google as a creative tool, while others will let Google do the thinking for them" (Anderson & Rainie, 2010, p. 11). As we move into a world where the boundaries between physical and digital are disappearing, acquiring the digital skills needed to thrive in this hybrid reality becomes a priority for our EM. "Stronger intellects" will undoubtedly be in a better disposition to acquire those digital skills and to prosper in an ever-increasing complex society.

Conclusions and Future Perspectives

The cognitive system extends to the entire environment in which the organism is immersed. Understanding the human mind requires to consider the human-computer interaction. The way in which human beings think, perceive, and memorize is substantially shaped by the way they relate to technology. However, the present study shows that higher cognitive processes might be unequally shaped between men and women, grounded on differential purposes for using technology. Men seem not to be afraid to explore and experiment with emerging technologies (e.g., VR), especially for recreational purposes, whereas women prefer topics related to self-projection (e.g., fashion) and for learning purposes.

Nevertheless, this work presents some limitations that may affect the interpretation of the findings. A major concern is the sampling method employed. Since it was a non-probability sample mainly recruited through social media networks and with Spanish speaking fluency as an inclusive criterion, the results may be difficult to be generalized. Furthermore, the fact that most participants interacted via social media networks could imply that the sample was above average in digital competences compared to the general population. Future research would have to address this limitation.

Besides, the directionality of the relationships cannot be determined from the measures taken in this study. There is a need for more experimental research in order to improve the understanding of how technology might impact human cognition, particularly thinking and reasoning. Unfortunately, there seems to be not much room to find places and individuals "untouched" by technology, especially in Western countries.

Additionally, future research needs to explore in detail the goals held by users when interacting with technology. For instance, one can spend more or less time surfing through social media, but with different goals in mind. Social media can be used to upload videos, stay connected with others, keep informed, or for self-promotion, among other things.

Those uses require different cognitive resources. For example, metacognition is required to use social media for self-promotion, whereas not much cognitive effort is needed to watch videos just for entertainment.

Moreover, future investigations should include more accurate measures of digital behavior. Most of the research to date in the field relies on self-report methods, which in some cases are unreliable or unable to capture specific nuances in digital behavior (Ellis, 2019; Geyer et al., 2022). Collecting automatized data would improve understanding of digital behavior, as negative consequences of self-report measures, such as social desirability, would be controlled. However, challenges related to privacy would need to be addressed.

Finally, more reasoning measures need to be added to get a better picture of the relationship between digital behavior and reasoning. For instance, the Cognitive Reflection Test (Frederick, 2005; Toplak et al., 2011) aims to distinguish between two different cognitive profiles, one more intuitive and other more reflective (Pennycook et al., 2016). It can be argued that those who rely more often on digital technologies, especially those with compulsive or problematic digital behavior, are more likely to have an intuitive cognitive profile, since the instant gratification provided by technology encourages this behavior. Further research is needed to confirm this hypothesis.

Over a decade ago, Nicholas Carr (2008) was afraid of the changes his brain was suffering because of his continuous use of the Internet. He wondered if Google was making humans stupid. Although the consequences of the pervasive use of digital technologies on higher cognitive processes are not fully understood today, this investigation supports the idea that Nicholas Carr was wrong, Google is not making men and women stupid. And gender matters.

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Appendix A

The following information is provided in this appendix:

1. Instruments for data collection
2. Supplementary data

1. Instruments for Data Collection (SPSS codes are included in brackets)

SEC I. Demographics

1. Id (ID)
2. Age (AGE)
3. Gender (GENDER)
4. Education (EDU)
5. Spanish fluency (inclusion criterion)

SEC II. Digital Devices Used

How much time do you spend DAILY using the following digital devices?

	I do not have it/do not use it	Less than 1h	1h-2h	2h-3h	4h-5h	5h-6h	More than 6h
TV (DEV1_TV)							
Smartphone (DEV2_SMARTPHONE)							
Computer/Laptop (DEV3_COMPUTER)							
Video console (DEV4_VIDEOCONSOLES)							
EBook (DEV5_EBOOK)							
Smartwatch (DEV6_SMARTWATCH)							
Digital Assistant (e.g., Cortana, Alexa, etc.) (DEV7_ASSISTANT)							
Other (DEV8_OTHER)							

SEC III. Uses of Digital Devices

How often do you use digital devices for the following purposes?

	Never	Rarely	Sometimes	Frequently	Always
Searching for information (U1_SEARCHINFO)					
Keep updated and informed (U2_UPDATED)					
Watching videos (e.g., You Tube, Twitch, Vimeo, etc.) (U3_VIDEO_WATCH)					
Social Media Networks (e.g., Instagram, Facebook, Twitter, etc.) (U4_SoNet)					
Checking Tutorials (e.g., cooking, carpentry, decoration, etc.) (U5_TUTORIALS)					
Online Shopping (e.g., clothes, tickets, devices, books, etc.) (U6_SHOPPING)					
Video calls and Video chats (e.g., Skype, Discord, WhatsApp, etc.) (U7_VIDEO_CONF)					
Elaboration and Editing Videos (U8_VIDEO_EDIT)					
Elaboration and Editing Documents (Word, PowerPoint, Pdf, etc.) (U9_DOCUMENT_EDIT)					
Software for Analysis and Calculus (Excel, SPSS, etc.) (U10_DATA)					
Playing Video Games (U11_VIDEO_GAMES)					
Running own Blog or Website (U12_PERSONALWEB)					
Working with Simulators (e.g., driving, flying, experiments, etc.) (U13_SIMULATORS)					
Using Virtual, Augmented or Extended Reality (U14_VR)					
Collaborative Learning (U15_COL_LEARNING)					
Online Learning (e.g., MOOC) (U16_ONLINE_LEARNING)					
Self-Monitoring (e.g., calories, steps, finances, etc.) (U17_SELF_MONITORING)					
Participating in Digital Communities (e.g., Wikipedia, Reddit, etc.) (U18_ACTIVISM)					

SEC IV. Online Content Searched

When surfing online, how often do you search for the following contents?

	Never	Rarely	Sometimes	Frequently	Always
Science (CONT1_SCIENCE)					
Breaking News (CONT2_ BREAKINGNEWS)					
Technology (CONT3_TEC)					
Fashion (CONT4_FASHION)					
Nutrition (CONT5_NUTRITION)					
Traveling (CONT6_TRAVEL)					
Sports (CONT7_SPORTS)					
Politics (CONT8_POLITICS)					
Curiosities (CONT9_CURIOSITIES)					
Humor (CONT10_HUMOR)					
Other (CONT11_OTHER)					

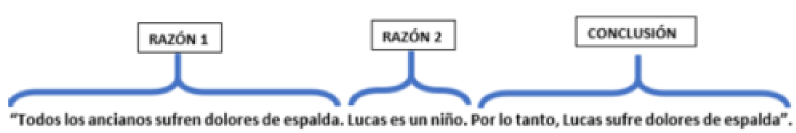
SEC V. Reasoning Tasks

Syllogisms

Instructions to solve syllogisms and an example were provided. Instructions were detailed as follows:

Next, we ask you to solve several reasoning tasks. By reasoning we understand the process we have to apply to reach a conclusion from some reasons or premises. This is an example of reasoning:

In this example of reasoning (known as "syllogism") three parts are differentiated. The last part of the reasoning is known as "the conclusion (C)". In our example, it would be the last sentence, that is. "Por lo tanto, todos los buitres son mortales" ("Therefore, all vultures are mortal"). To reach that conclusion we use two reasons or premises, R1 would be "Todos los buitres son aves" ("All vultures are birds") and R2 would be "Todas las aves son mortales" ("All birds are mortal"). To the question "Can we reach this conclusion from these reasons", the answer is "yes". We would say the reasoning is valid.



Imagine another example of reasoning:

In this second example, we again use two reasons, R1: "Todos los ancianos sufren de dolor de espalda" ("All elderly people suffer from back pain"), and R2: "Lucas es un niño" ("Lucas is a boy") to reach another conclusion, C: "Lucas sufre dolores de espalda" ("Lucas suffers from back pain").

To the question "Can we reach this conclusion from these reasons", in this case the answer is "no". We would say that the reasoning is invalid.

The following are the syllogisms we asked participants to solve (correct answers are highlighted in bold):

Syl1

"All fishes go under water (R1). Salmon is a type of fish (R2). Therefore, salmons go under water (C)". Can we reach this conclusion considering only and exclusively these reasons?

a) Yes, this conclusion can be reached by using only and exclusively these reasons.
b) No, this conclusion cannot be reached using only and exclusively these reasons.
c) It is not possible to know. There is a lack of information.
d) I do not know the right answer.

Sil2

."Some foods are not nutritive (R1). Spinach is a type of food (R2). Therefore, spinach is not nutritive (C)". Can we reach this conclusion considering only and exclusively these reasons?

a) Yes, this conclusion can be reached using only and exclusively these reasons.
b) No, this conclusion cannot be reached by using only and exclusively these reasons.
c) It is not possible to know. There is a lack of information.
d) I do not know the right answer.

Syl3

"Some athletes are not good competitors (R1). Runners are athletes (R2). Therefore, some runners are not good competitors (C)". Can we reach this conclusion considering only and exclusively these reasons?

a) Yes, this conclusion can be reached using only and exclusively these reasons.
b) No, this conclusion cannot be reached by using only and exclusively these reasons.
c) It is not possible to know. There is a lack of information.
d) I do not know the right answer.

NOTE: Syllogisms from 4-6 mirrored the same structure than syllogisms from 1-3, respectively, but with meaningless words.

Syl4

"All afles go under water (R1). Golne is a type of afle (R2). Therefore, golnes go under water (C)". Can we reach this conclusion considering only and exclusively these reasons?

a) Yes, this conclusion can be reached by using only and exclusively these reasons.
b) No, this conclusion cannot be reached using only and exclusively these reasons.
c) It is not possible to know. There is lack a of information.
d) I do not know the right answer.

Syl5

"Some medisan are not delloce (R1). Capir is a type of medisan (R2). Therefore, capir are not delloce (C)". Can we reach this conclusion considering only and exclusively these reasons?

a) Yes, this conclusion can be reached using only and exclusively these reasons.
b) No, this conclusion cannot be reached by using only and exclusively these reasons.
c) It is not possible to know. There is lack a of information.
d) I do not know the right answer.

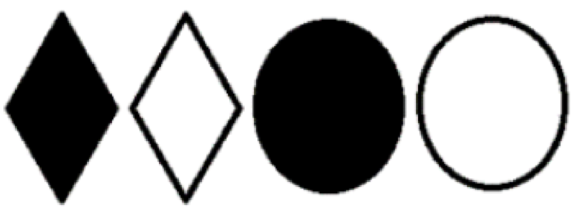
Syl6

"Some larupecos are not good surais (R1). Banovas are larupecos (R2). Therefore, some banovas are not good surais (C)". Can we reach this conclusion considering only and exclusively these reasons?

a) Yes, this conclusion can be reached using only and exclusively these reasons.
b) No, this conclusion cannot be reached by using only and exclusively these reasons.
c) It is not possible to know. There is lack a of information.
d) I do not know the right answer.

THOG Task

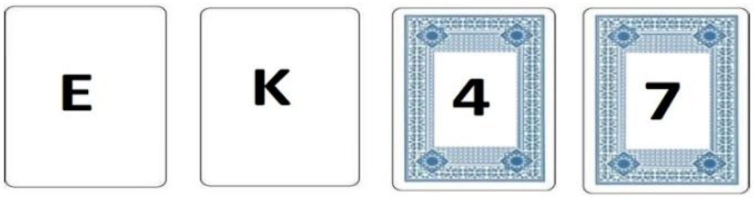
Imagine that on a piece of paper I have written one color (either white or black) and one shape (either circle or rhombus). You know that the following statement is true: "If and only if a figure includes either the color or the shape I have written on the piece of paper, but not both, then it is a THOG". In addition, you know that the black rhombus is a THOG. Deduce whether the white rhombus, the black circle, and the white circle are: a) a THOG, b) no THOG or, c) it is not possible to know.



	…is a THOG	…is not a THOG	…is not possible to know if it is either a THOG or not	I do not know the right answer
The black diamond is…	**X**			
The white diamond is…		**X**		
The black circle is…		**X**		
The white circle is…	**X**			

Wason's Selection Cards

Imagine you have the following four cards in front of you (see picture below). On one side of the card there is a letter. It can be either a vowel or consonant. On the other side, there is a number. It can be either an even or an odd number. I claim the following: "If on one side of the card there is a vowel, then on the other side you will find an even number". Which card or cards should you turn over in order to determine if the statement is true or not? Select all the ones that you think apply.



- **E**
- K
- 4
- **7**

2. Supplementary Data

Table S1

Differences Between Men and Women on Each of the Reasoning Tasks and the Total Reasoning Score

Task	Men		Women		$t(220)$	p
	M	*SD*	*M*	*SD*		
Syllogisms (0-6)	3.95	1.298	3.89	1.092	0.376	>.05
THOG (0-4)	1.43	0.997	1.46	1.061	0.245	>.05
Wason's Selection Card (0-1)	0.10	0.295	0.09	0.283	0.208	>.05
Total reasoning score (0-11)	5.48	1.766	5.44	1.657	0.145	>.05

Figure S2

Mean of Total Score on Reasoning Tasks as a Function of Gender, Daily Smartphone Usage Time and Education Level