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Presbycusis and Theory of Mind. Study on the limitations of people with presbycusis to understanding the intentions of the person with whom they are speaking

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1. INTRODUCTION

Presbycusis, or age-related hearing loss, is the most common cause of hearing loss (Gates, 2012). It is considered the third most common chronic pathology in the elderly, usually affecting one-third of the population over the age of 65, and its incidence, in line with the increase in life expectancy of the world's population, is on the rise (World Health Organization [WHO], 2021).

Depending on the degree of hearing impairment and the logical individual differences, presbycusis often has a negative impact on the quality of life (Borel, 2020; Manrique, 2021) and psychological well-being of the individual (Humes *et al.*, 2020), especially in its more advanced stages. There is also frequent scientific literature highlighting the high comorbidity between presbycusis and mental deterioration or dementia, although the terms defining this relationship are not yet conclusive, as aging itself may be a cause of these diseases (Lin *et al.*, 2011; Amieva *et al.*, 2018; Uchida *et al.* 2019; Croll *et al.*, 2020). Its most immediate consequence affects speech comprehension, but the mastery of pragmatics and social participation are often also compromised (Borel, 2020).

Thus, in addition to problems in speech perception, presbycusis can lead to difficulties in recognising the intentions of their interlocutor by impairing the ability to understand non-literal language (Goy *et al.*, 2018; Pearlman-Avnion, *et al.*, 2018). These communication impairments affecting people with presbycusis undoubtedly hinder their interpersonal relationships (Borel, 2020).

To facilitate communication for people affected by presbycusis, one of the alternatives provided by technology are hearing aids or cochlear implants, though the studies analysing their effects on improving the quality of life of people with presbycusis are still insufficient and inconclusive. In fact, some studies highlight that at least two-thirds of people with hearing impairment do not use any electroacoustic devices (Fischer, 2011). However, most recent work tends to confirm the premise that the use of hearing aids or cochlear implants contributes to slowing cognitive decline and, in sum, to the improvement of the quality of life of their users (Monfort-Huarte *et al.*, 2016; Amieva and Ouvrard, 2020; Sarant *et al.*, 2020; Lassaletta *et al.*, 2021).

Understanding non-literal language is one of the competencies required for Theory of Mind (ToM). This term refers to the ability to attribute mental states to others, differentiating them from one's own, and thus predict and explain their behaviours, desires, intentions, beliefs and feelings (Premack and Woodruff, 1978). It is therefore a skill that facilitates interpersonal relations and reduces the risk of misunderstanding in communication (Hughes and Leekam, 2004).

ToM has been one of the most complex and studied psychological constructs in recent decades. Different tasks have been devised for its evaluation, but most of them remain unvalidated. Thus, the tasks of facial recognition of emotions (Baron-Cohen *et al.*, 1999), or the comprehension of short stories that require the inference of ToM meanings such as the attribution of false beliefs, sarcasm, inappropriate social behaviour, etc. (Happé *et al.*, 1998 or Shamay-Tsoory and Aharon-Peretz, 2007) are well known.

The most recent studies tend to confirm the premise that the use of hearing aids or cochlear implants contributes to slowing cognitive decline and, ultimately, to improving the quality of life of their users

Regarding the assessment of ToM in older people, it is generally considered that, with age, comes a certain decline in ToM abilities (Henry *et al.*, 2013; Stietz et *al.*, 2021), but other studies do not subscribe to these conclusions, considering that, rather than age, one factor that has a greater impact is the cognitive state of the person being examined (Duval *et al.*, 2011). These discrepancies in the results may be due, in our opinion, both to the different age ranges used in these studies and to the particularities of the different assessment instruments used.

Some of these lines of research relate ToM abilities in older people to both so-called cognitive reserve (Li *et al.*, 2013), social activity (Henry *et al.*, 2013) and gender (Pinkham *et al.*, 2017).

Although ToM in deaf people has been the subject of intense research, little work has focused on the analysis of these skills in adults, and more specifically in adults with presbycusis. Therefore, it seems useful to know to what extent people with presbycusis have similar ToM profile to other older people without this hearing impairment or if, as it would seem logical to think, the presence of presbycusis has a greater deteriorating effect on these skills, which would undoubtedly contribute to the limitations in the social relations of these people. Such studies could help to better characterise pragmatic difficulties in people with presbycusis and facilitate the design of appropriate intervention plans to improve their quality of life.

2. STUDY OBJECTIVES AND HYPOTHESES

This study explored the relationship between presbycusis and ToM. More specifically, our objectives were to determine whether there are significant differences in ToM in people with presbycusis compared to people of the same age without hearing problems and to explore the effect that the use of hearing aids may have on the preservation of ToM skills.

To this end, we set out the following questions: 1.- Do people over 64 years of age with presbycusis have a lesser ability to perform ToM tasks than hearing people of the same age? 2.- Assuming there are some differences, which factors might be more important: hearing loss, cognition, social activity? 3.- Can the continued use of hearing aids (more than eight hours a day) help preserve ToM abilities in the population with presbycusis?

The study adhered to the principles of the Declaration of Helsinki, using the clinical method of data collection based on semi-structured interviews and the administration of non-harmful tests

To try to answer these questions, we devised the following hypotheses:

[H1].- People affected by presbycusis are significantly impaired in their ToM abilities in relation to their hearing peers.

[H2].- In the group of people with presbycusis, hearing aid users have significantly better preserved ToM abilities than those who do not use hearing aids.

[H3].- Age, gender, cognitive reserve, hearing loss, verbal competence and social activity are variables that significantly influence the results obtained both in the sum of ToM stories and in the comprehension of non-literal language -sarcasm-.

3. METHOD

3.1. Ethical safeguards

The study was approved by the Ethics and Research Committee of the Universitat Ramon Llull, Barcelona, in 2021. The study followed the principles of the Declaration of Helsinki, using the clinical method of data collection through semi-structured interviews and the administration of non-harmful tests. Participation was voluntary and subject to informed consent. For this purpose, the collaboration of the users of different Municipal Leisure Centres for the Elderly[1], of a Social-Healthcare Centre in the metropolitan area of Barcelona[2], Geriatric Centre in Barcelona[3] and of the Catalan Association of Families and People with Deafness (ACAPPS) was requested at random. Exclusion criteria were 1) history of other neurological disease, behavioural disorders or epilepsy, 2) history of psychiatric illness, or 3) mild or moderate cognitive impairment.

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3.2. Participants

The sample of older adults examined initially consisted of 141 persons (95 women and 46 men; M= 77.9 years; SD= 8.2; Range= 65-94 years).

3.3. Materials and procedure

The people who participated in the study were first interviewed to fill in their socio-demographic data. The individual administration of the following tests was then initiated:

1/ Cognitive examination.

WAIS IV Matrix Reasoning and Vocabulary Tests (Wechsler, 2012). The minimum score required to be included in the study sample was set at 7 scalar points. For this reason, 16 people were excluded. This test also gave us an insight into the cognitive ability of the people studied.

1 Casal d'avis de Lliçà d'Amunt and Esplai municipal de Sant Fruitós de Bages, both located in the province of Barcelona.

2 Clínica Sociosanitaria Ntra. Señora de Guadalupe de Esplugues del Llobregat.

3 Sanitas Altanova Geriatric Centre; Torrassa Geriatric Residence and Rosben Residential Centre.

2/ ToM examination.
For the so-called ToM task solving, 8 stories were used. The stories used were adapted from Happé *et al.* (1998), Baron-Cohen, *et al.* (1999), Birch and Blomm (2007) and Shamay-Tsoory and Aharon-Peretz (2007). They show scenes of real life, allowing us to infer the intentions, emotion and/or beliefs experienced by the characters. Each of the stories was explained verbally to each participant in the same order, with the text and a pre-designed illustrative image for each story. The 8 ToM stories used are shown in Figures 1 to 4 of the Annex. The average number of words used in each story was 72.5.
Correctly solving this task involved identifying the intention behind each character's comment. Following the scheme used by Happé *et al.* (1998), the criteria for assessing the results were: 2 points, correct reference to ToM aspects of the protagonists of the story; 1 point, partial or unclear ToM reference; 0 points, incorrect answer. Scores ranged from 0 to 16 points. Prior to this, a validity test was carried out for the established scoring criteria. For this purpose, six experts, acting as a jury, scored the answers of a total of 10 participants. Initially, a Kappa index of 0.759 was obtained and, after reformulating the correction instructions, a Kappa index of 0.807 was finally obtained.
3/ Administration of the Geriatric Depression Scale-GDS- (Sheik and Yesavage, 1983; cited by Martínez de la Iglesia *et al.*, 2002). Some studies highlight that depression is often associated with a clear risk of functional decline and, consequently, weaken the results of any screening (Alexopoulos *et al.*, 2005). For this reason, the GDS was used as a test to determine the mood of the person being examined, and the cut-off threshold for excluding a participant was set at 20 points. None of the participants were excluded for this reason.
4/ Administration of the Cognitive Reserve Index Questionnaire. (Rami *et al.*, 2011). This questionnaire was administered in order to have a record that could later be correlated with the results obtained in the ToM tests.
5/ Hearing examination.
Tonal liminal audiometry was performed to determine hearing thresholds (between 0.5 and 8 kHz) following the methodology established by the American Speech-Hearing-Language Association [ASHA] (1978). For the calculation of hearing loss, the criteria of the International Bureau for Audiophonology [BIAP] (1997) were adopted. To determine when a person had presbycusis, the WHO (2021) criteria were adopted: binaural and postlingual hearing loss, occurring after the age of 50 years, greater than 40 dB in the better ear.

3.3 Statistical analysis

The sample was divided into three groups: people without presbycusis, people with presbycusis using hearing aids and people with presbycusis not using hearing aids. Using the IBM SPSS Statistics package, version 26.0 (IBM, Corporation., 2019), a descriptive and an inferential statistical analysis were performed. At the descriptive level, the characteristics of the population are highlighted, reporting average values and standard deviation for continuous variables and percentages for qualitative variables. At an inferential level, a comparison was made of the scores obtained in the different tests carried out, using Student's t-test when the comparison was made between two groups, or an ANOVA, if the comparison was made between three groups; all of which made it possible to observe those independent variables that report statistically significant differences between the different subgroups of the sample. A regression model was then used to examine the associations between statistically significant independent variables with overall ToM scores and with ToM stories involving comprehension of sarcasm. The results were analysed taking into account the p-values of statistical significance. The minimum level of statistical significance of $p<0.05$ was chosen.

4. RESULTS

The final study sample was 125 people, 41 of whom had no hearing loss greater than 40 dB in the better ear and 84 had presbycusis. Of these, 29 (34.5%) were hearing aid users and 55 (65.5%) were not. A total of 49.6% of the participants had had less than 8 years of schooling. A total of 24.8% had completed primary or secondary school (8-14 years of schooling) and 25.6% had higher education. Table 1 shows the main socio-demographic data for each of these two groups: hearing people and people with presbycusis. The mean scores obtained by each group in the sum of the ToM tests and the statistical significance of each of these variables are also shown.
From the data provided, we can highlight the significant differences found between the two groups in terms of age and, logically, hearing loss ($p<0.001$). Significant differences are also observed, although to a lesser degree, in the variables depressive symptoms, verbal rea-

soning and logical reasoning; in the sense that people with presbycusis tend to have a higher propensity to present depressive symptoms(p<0.01) and a lower capacity for verbal and logical reasoning (p<0.05). However, the most relevant data is the difference found between the sum ToM scores for both groups, in the sense that the group of people with presbycusis scores significantly lower than the group of hearing peers (p<0.001). The data obtained in the screening were then regrouped by separating the group of people with presbycusis into two distinct groups: hearing aid users and non-users[4].

TABLE 1: *Socio-demographic data of the sample studied and average scores obtained in the sum total of the ToM stories administered.*

Variables covered	Adults without presbycusis (n=41)	Adults with presbycusis (n= 84)	*Statistical significance*
Participant characteristics			
• Age (1)	73.0 (6.1)	80.5 (8.13)	***
• Sex	26.8%M/73.2%F	35.7%M/64.3%F	
Education			
• <8 years %	41.5%	53.5%	
• 8-14 years %	22.0%	26.1%	
• >14 years %	36.5%	20.2%	
Depressive symptoms			
• GDS (1)	1.88 (1.91)	2.88 (2.04)	**
Cognition			
• Cognitive reserve (1)	11.56 (4.86)	9.67 (4.87)	
• Verbal reasoning (1)	12.07 (3.46)	10.83 (3.04)	*
• Logical reasoning (1)	12.10 (3.20)	10.90 (3.15)	*
Binaural hearing loss (1)	30.5 dB (5.8)	52 dB (9.1)	***
Sum ToM (1)	11.56 (3.1)	9.30 (3.56)	***

(1) Data refer to mean scores and standard deviation.
* p<0.05
** p<0.01
*** p<0.001

4 Some people were aware of their hearing problems, but voluntarily did not wish to wear a hearing aid. Most, however, were not aware of this problem.

Table 2 shows both the main socio-demographic data of the sample and the results obtained from the ToM stories of the three resulting groups: (A) people with no hearing problems; (B) people with presbycusis who do not use hearing aids; and (C) people with presbycusis who use hearing aids. Moreover, the different ToM stories were grouped into different domains, according to the ToM theme addressed: sarcasm, false belief, social skills and persuasion. In relation to the results obtained globally in the ToM tests, the sum of ToM stories was maintained.

TABLE 2: *Socio-demographic data of the sample studied and overall results of the tests carried out, considering the use of auditory prostheses*

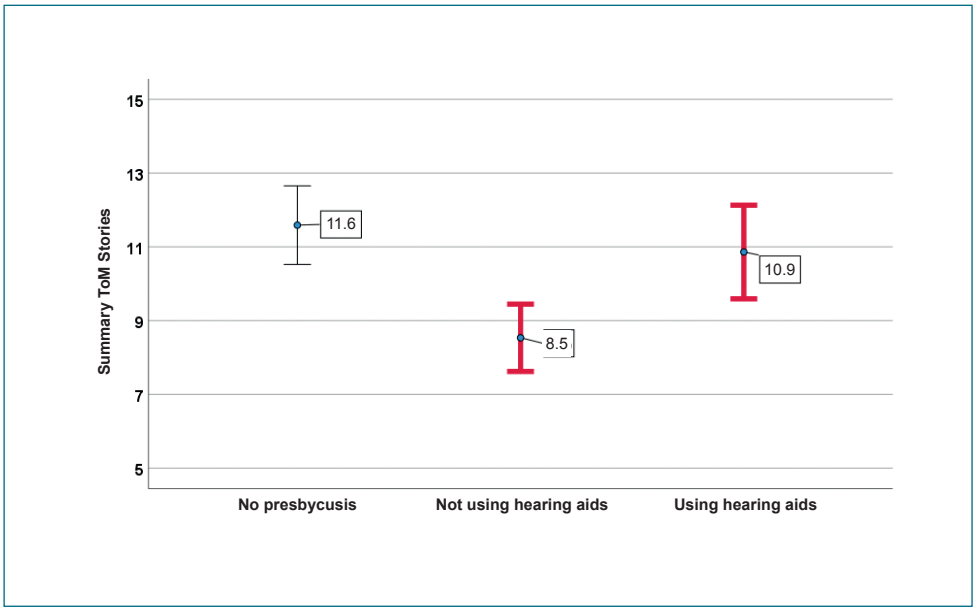
	A	B	C	A-B	A-C	B-C
Variables covered	Adults without presbycusis (n=41)	Non-hearing aid users (n=55)	Hearing aid users (n=29)	*Statistical significance*		
Participant characteristics • Age (1) • Sex	73.0 (6.1) 26.8%M/73.2%F	79.8 (8.4) 34.5%M/65.5%F	81.2 (7.6) 40%M/60%F	***	***	
Education • <8 years % • 8-14 years % • >14 years %	41.5% 22.0% 36.5%	63.3% 21.8% 14.5%	34.5% 34.5% 31.0%			
Social activity	1.56 (0.75)	1.24 (0.75)	1.48 (0.68)			
Depressive symptoms • GDS (1)	1.71 (1.80)	3.28 (2.3)	2.03 (1.45)	***		*
Cognition • Cognitive reserve (1) • Verbal reasoning (1) • Logical reasoning (1)	11.56 (4.86) 12.20 (3.53) 12.25 (3.20)	8.51 (4.33) 10.11 (2.59) 10.53 (3.01)	11.93 (5.10) 12.24 (3.37) 11.62 (3.32)	** ** *		** **
Binaural hearing loss (1)	30.5 dB (5.8)	50 dB (8.4)	56 dB (9.1)	***	***	*
ToM Sarcasm - Bank (1) - Absent-minded father (1)	1.52 (0.74) 1.51 (0.77)	1.01 (0.80) 0.73 (0.74)	1.62 (0.56) 1.52 (0.78)	** ***		*** ***
ToM False belief • Violin (1st order) (1) • Prisoner (2nd ord.) (1) • Salesperson (2nd ord.) (1)	1.95 (0.21) 1.27 (0.86) 0.85 (0.88)	1.82 (0.51) 0.91 (0.91) 0.60 (0.71)	1.79 (0.62) 1.24 (0.83) 0.72 (0.84)			
ToM Social skills • Curtains (1) • Teacher (1)	1.80 (0.40) 0.95 (0.92)	1.62 (0.62) 0.42 (0.74)	1.59 (0.68) 0.83 (0.92)	***		
ToM Persuasion • Kittens (1)	1.78 (0.52)	1.42 (0.76)	1.62 (0.56)	*		
Sum ToM (1)	11.67 (3.28)	8.50 (3.38)	10.86 (3.33)	***		**

(1) Data refer to mean scores and standard deviation.
* $p<0.05$
** $p<0.01$
*** $p<0.001$

In relation to the distribution of the sample of Group B (people with presbycusis not using hearing aids) and Group C (people with presbycusis using hearing aids) in relation to sex and schooling, statistically significant differences were observed through Chi-squared tests (χ^2 =0.17, p>0.05) and (χ^2 =8.19, p>0.05), respectively. To find out whether there were significant differences for the other socio-demographic data and between the responses to the ToM stories among the three groups, a one-factor ANOVA analysis was performed, not assuming equality of variances and adjusting the significance values by Dunnett's correction. The differences found, when comparing the mean scores obtained between groups (A) and (C), were non-existent except for age and, logically, the hearing loss recorded. On the contrary, it was observed that between groups (A) and (B) the significant statistical differences were multiple, always favouring hearing people and affecting both age (p<0.001), depressive symptoms (p<0.001), cognitive reserve (p<0.01) and logical reasoning (p<0.05), and verbal reasoning (p<0.01), respectively, and, obviously, the degree of hearing loss (p<0.001). With regard to the ToM stories, significant differences were observed in the scores obtained in the stories “bank” (p<0.01) and “absent-minded father” (p<0.001), both referring to the domain of sarcasm; “teacher” (p<0.001), referring to the domain of social skills; and “kittens”, referring to the domain of persuasion (p<0.05).

Finally, statistically significant differences were also observed in the sum of all ToM stories administered (see *Figure 5*). The group of people with presbycusis who did not use hearing aids (Group B) presented significantly lower results, with different degrees of statistical significance, both in relation to the group of people without presbycusis (p<0.001) and to the group of people using hearing aids(p<0.01). In contrast, between the group of people without hearing problems (A) and the group of hearing aid users (C) the differences were statistically insignificant (p>0.05).

FIGURE 5: Results obtained by each of the sample groups in the ToM tests as a whole.

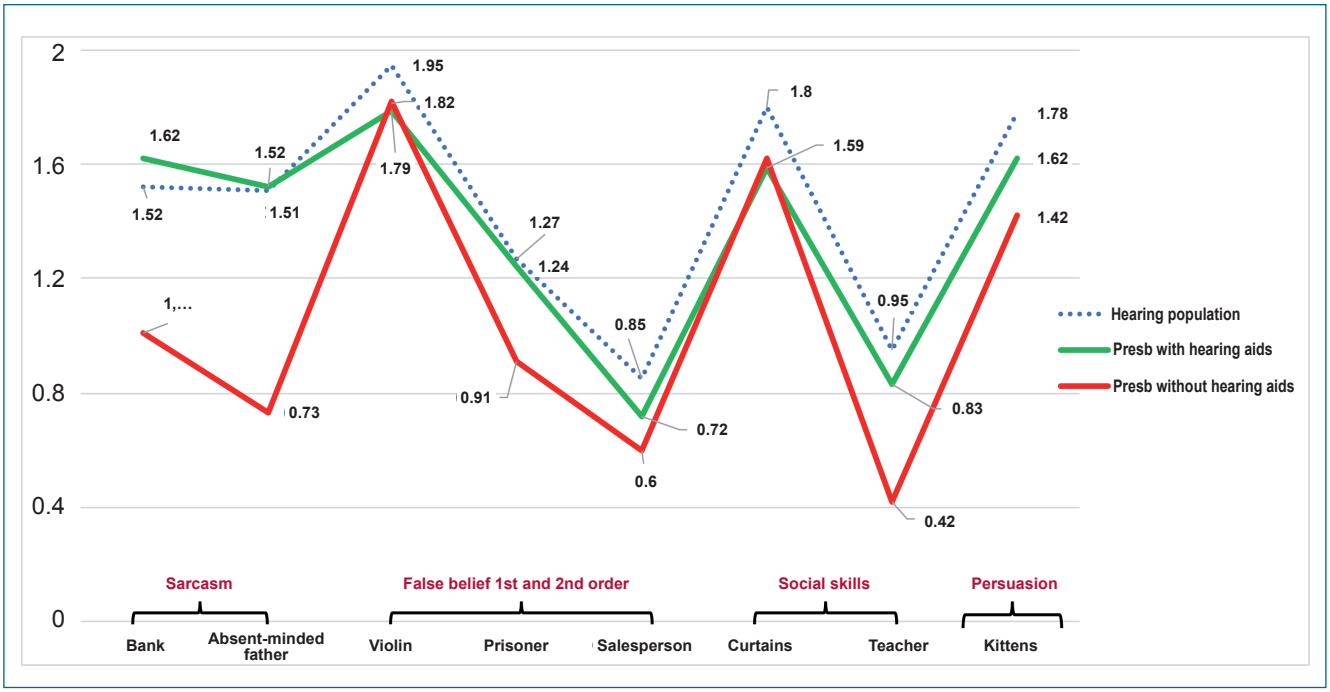


A graph showing the mean scores for each of the stories obtained by Groups B and C can also be seen in Figure 6. Thus, it can be seen that the scores recorded were somewhat more favourable for the group of people using hearing aids (Group C) than for the group not using hearing aids (Group B). Only in the ToM stories related to the understanding of sarcasm is the difference more evident (p<0.001). In this respect, the above-mentioned trend was observed: the group of people with presbycusis who do not use hearing aids performed significantly worse than those who use hearing aids. And,

People with presbycusis who do not use hearing aids performed worse than hearing aid users. On the other hand, they did not show any significant difference compared to the hearing group

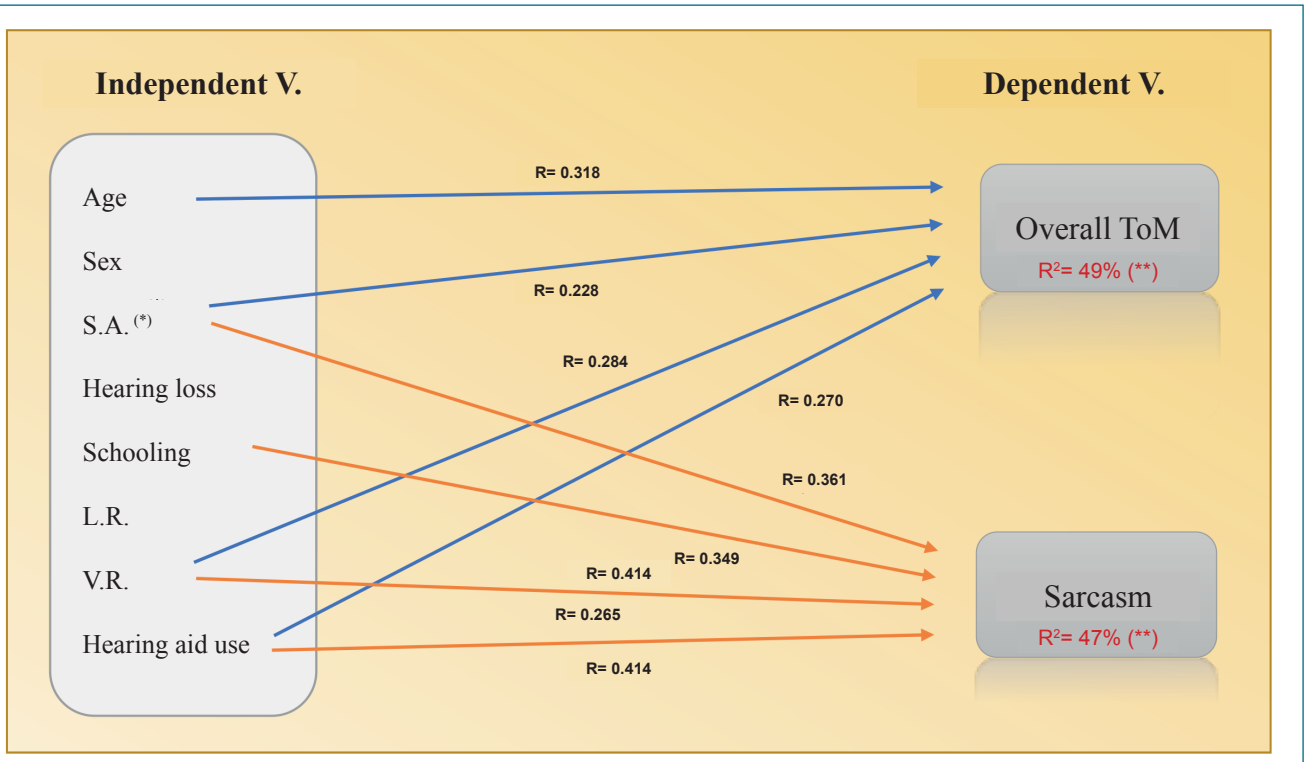
on the other hand, they did not show any significant differences compared to the hearing population in any of the ToM domains analysed.

FIGURE 6: RESULTS obtained in the ToM stories.



Next, and only for Groups B and C, we proceeded to determine the impact of each of the variables that were shown to be statistically significant on the sum of the ToM stories and on the understanding of sarcasm. This allowed us to obtain information on which factor(s) have an impact on the best level of development of both dependent variables (DV). For this purpose, a simple linear regression analysis was carried out. The most influential factor on ToM task performance was initially social activity, which predicts almost 50% of the observed differences in ToM tasks (R= 0.499). However, its effect fades with the mediation of other variables such as age (R=-0.318), verbal reasoning ability (R=0.284) and hearing aid use (R=0.270). In relation to sarcasm comprehension, the use of hearing aids appears as the most influential factor with 41% predictive ability (R=0.414). Behind them are social activity (R=0.361), level of schooling (R=0.349) and verbal reasoning ability (R=0.265). Variables such as cognitive reserve, logical reasoning ability, gender or hearing loss do not appear in any of the statistical models provided. (see *Figure 7*).

FIGURE 7: Influence of the IVs covered in this study on the variance of the overall ToM and understanding of sarcasm.



S.A. = Social activity
L.R. = Logical reasoning
V.R. = Verbal reasoning
Cog. R.= Cognitive Reserve

Note: (*) Variable that, when acting in interaction with the other IV, loses impact on the overall ToM scores.
(**) Percent variability explained by the model.

5. DISCUSSION

The results of this study fully confirm the first hypothesis formulated [H1]. Taken as a whole, older people with presbycusis have significantly lower ToM task resolution than older people without presbycusis (see *Table 1*). However, and this may be one of the most interesting contributions of this study, if we consider the second hypothesis formulated [H2] and subdivide the group of people with presbycusis into two subgroups, those who do not use any type of hearing prosthesis (Group B) and those who do use hearing aids (Group C), we can see that the results of the first group present frequent statistically significant differences in relation to the results shown by their hearing peers (Group A) (*Table 2*). These differences are especially relevant when we look at the results for stories with sarcastic content ($p<0.001$; and $p<0.01$) and also for the sum ToM ($p<0.001$) (*Figure 5*). In contrast, *Figure 6* shows that the results for the simpler ToM stories (violin or curtains) show irrelevant statistical differences. On the other hand, in the tasks with a more complex cognitive component (prisoner and salespeople) the mean scores obtained were rather low in both groups, but the differences found were not statistically significant. The reason may lie in the very cognitive complexity of the stories, which makes them difficult for older people to understand, regardless of their hearing condition.

Thus, according to the results of this study, people with presbycusis who regularly use hearing aids tend to have better preservation of ToM abilities. In this respect, there are practically no statistically significant differences between the different ToM tests performed by Group A and the group with presbycusis and hearing aids (Group C) (*Figure 6*). These results would be in line with what many authors nowadays emphasise in their work, in the sense that untreated presbycusis is not only an auditory problem, but a problem that also affects the social-emotional sphere of human development (Borel, 2020; Manrique, 2021). In the particular case of sarcasm, where comprehension of non-literal utterances is assessed, comprehension is largely based on the perception of clues contained in the prosodic elements of the interlocutor's speech. This is precisely a paralinguistic aspect that is difficult to perceive for anyone with presbycusis who does not use a hearing aid. However, it is also worth noting that impaired access to communication due to untreated presbycusis leads to a progressive disconnection from the environment, an impoverishment of social relations and, in short, a general deterioration of living conditions. To maintain ToM, it is necessary to continue to maintain the person's experiences in the social world and the multiple settings in which people act. Without these circumstances, the capacity for ToM will, logically, be impaired.

In this study, we have made further efforts to control variables that could influence these outcomes, such as cognition or the presence of depressive symptomatology.

These results reinforce those obtained by part of the writing team in a first pilot study (Valero-Garcia *et al*., 2021). In the current study, we have gone further in controlling for variables that might influence these outcomes, such as cognition or the presence of depressive symptomatology. It is worth noting in this respect that, though no participant in the study presented disturbances in either of these two mental domains, the records obtained are always more favourable, and with statistically significant differences($p<0.01$ and $p<0.05$), for Groups A (hearing) and C (hearing aid users). Consequently, we see Hypothesis 2 confirmed, thus reinforcing the contributions of different authors such as Monfort-Huarte *et al.* (2016); Amieva and Ouvard (2020); Sarant *et al.* (2020) or Lassaletta *et al*. (2021), who highlight the importance of the use of hearing aids or cochlear implants to slow cognitive impairment, improve the quality of life of their users and, ultimately, facilitate the inclusion of people with deafness in their environment.

With regard to the third hypothesis [H3], the statistical model on the variables that have shown the greatest impact on ToM scores for people with presbycusis includes age, social activity, verbal competence and hearing aid use. That is to say, it surprisingly rejects both cognitive reserve and hearing loss (*Figure 7*). These data were certainly unexpected and, at the same time, encouraging. In short, they suggest that hearing loss in older people does not have a decisive influence on ToM, as long as hearing aids are used. The decline recorded in the sample of adults with presbycusis studied should be associated more with the cognitive, verbal reasoning, and socio-affective changes that result from this circumstance, since the results obtained by the group of people

using hearing aids suggest that the deterioration in their ToM skills is minimal in relation to their hearing peers.

In relation to the understanding of sarcasm, the results suggest that this is a ToM ability where both the level of academic studies and verbal reasoning ability have a significant influence. However, the influence of hearing loss per se is still not decisive, but the use of hearing aids is. Sarcasm is used to convey a message directly or indirectly opposite to what is literally said. Understanding sarcasm is based on three main markers: prosody, which is clearly affected by presbycusis; context; and lexis. From this perspective, the results of the study are consistent and emphasise the idea that not addressing presbycusis early on makes people unable to understand the true intentions of other speakers, thus making them more vulnerable to all kinds of deception.

6. CONCLUSIONS

The measured ToM story scores observed in this study help us to understand the social functioning of people with presbycusis and, although the results in each domain are independent, they do provide interesting information about this construct. The study shows that people with presbycusis who use hearing aids perform better than people who have not been fitted with hearing aids, and their scores are fairly comparable to those of the sample of older hearing people. Hearing loss alone does not seem to maintain a decisive influence on outcomes, and it can be mitigated by the use of hearing aids. Meanwhile, other variables such as age, along with verbal reasoning ability, greater social activity and the use of hearing aids have been shown to be much more influential variables. With regard to the comprehension of stories with sarcastic content, the use of hearing aids, social activity and level of education appear to be the most decisive variables.

Hearing aids, and by extension auditory prostheses, not only help older people with presbycusis to perceive sounds more accurately, but also facilitate a better connection to the environment and indirectly preserve ToM skills. They, therefore, make these people less socially vulnerable.

7. LIMITATIONS

We believe that this topic could be further explored with a more detailed analysis of the quality of the social life of the people in the sample, as this is a fundamental variable for ensuring good ToM scores, and we believe that it has been insufficiently considered in our study.

Another aspect to consider could refer to the use of a larger number of stories representative of the ToM domains contemplated: sarcasm, false belief, social skills and persuasion; with different levels of inferences required. This would provide a better approximation of the effect that presbycusis, treated or untreated, has on each of them.

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9. ANNEX

FIGURE 1: ToM stories used to assess understanding of 1st and 2nd order false belief. Illustrations by Edgar González.

False belief 1st order

Violin
(Birch and Bloom, 2007)

This is Ana. When she finished playing her violin, she put it in the blue box. Then she went to play with a friend. While Ana was playing outside, her sister, Sonia, moved the violin from that box and put it in the green box. A little while later, Ana went back to her room to practice violin.

False belief 2nd order

Prisoner
(Happé *et al.*, 1998)

During the war, the green army captured a member of the yellow army. The green army wanted the prisoner to tell them where the tanks were. They knew that they were either near the sea or up in the mountains. They also knew that the prisoner would not want to tell and would do everything possible to cover up for his comrades; therefore, he would probably lie to them. The prisoner was very brave and very clever, and did not want his tanks to be found. The tanks were actually in the mountains. When asked where the tanks were, he replied: *"In the mountains".*

Salespeople

Two salespeople meet one morning in the Barcelona train station. Both are in the same business and are competitors, so they look at each other suspiciously and one asks the other:
-Where are you travelling today?
-Zaragoza, replies the other cautiously.
-Zaragoza, hmm? -he says skeptically.
-I know very well that you are saying that to make me believe that you are really going to Madrid. But I happen to know that you really are going to Zaragoza...
And after a brief pause, he adds, visibly angry:
So: Why are you trying to trick me?

FIGURE 2: ToM stories used to assess understanding of sarcasm. Illustrations by Edgar González.

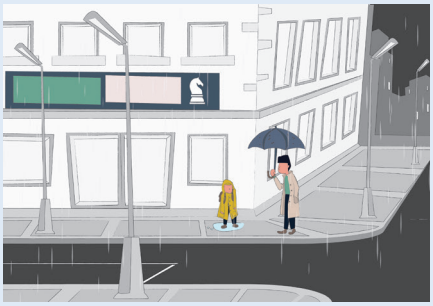
Sarcasm	**Messy office** (Shamay-Tsoory and Aharon-Peretz, 2007) Peter went to the bank and, while he waited, he looked for a place to sit, but all the seats were full of papers and folders. On the table was a pile of letters and documents in disarray. Peter said to a bank clerk: *"Your office is so tidy."* 	**Absent-minded father** (Shamay-Tsoory and Aharon-Peretz, 2007) Marcos' father had planned to pick his son up from chess club at 6pm. But by the time he remembered that he had to pick him up, it was already 7 o'clock. The father found his son tired and frightened in the rain. When they got home, Marcos explained to his mother what had happened. The mother looked at her husband and said: *"Seriously, you're such a great dad!"* 

FIGURE 3: ToM stories used to assess understanding of social skills. Illustrations by Edgar González.

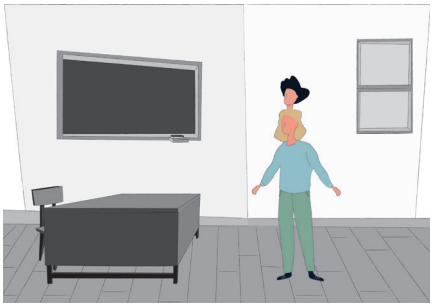
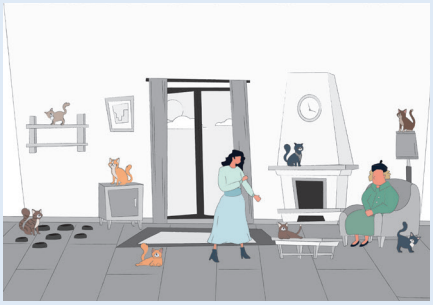
Faux pas	**Teacher** Ana arrives at school very worried because a head had grown out of her head and, crying, she told her teacher: *"a head growed out of my head"*. And the teacher responds: *"it's not growed, it's grew!"* 	**Curtains** *(Baron-Cohen, 1999)* Maria just moved into a new apartment. She bought some curtains for the bedroom. When her best friend came to visit her, she asked her, *"Did you see my pretty curtains?*". To which her friend replies: *"Those curtains are awful. I hope you get new ones."* 

FIGURE 4: ToM story used to assess understanding of persuasion. Illustrations by Edgar González.

Persuasion	**Kittens** (Happé *et al.*, 1998)  Marta was very fond of animals, so she went to visit Mrs. García who had a lot of cats. Mrs. Garcia loved her cats very much and did not want to harm them in any way, but since she could hardly afford to keep them, she considered selling them. When Marta visited Mrs. García, she had no intention of taking any of the kittens, because she already had a dog at home. Even so, Mrs. Garcia told her: *"If you don't take any of the kittens I'll have to drown them".*

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