Title: Use of adjectives in prediction during spoken language comprehension in older adults: Evidence from anticipatory eye-movements

Anurag Anurag & Niharika Singh
Centre of Behavioural and Cognitive Sciences,
University of Allahabad

Corresponding Author:

Niharika Singh

Centre of Behavioural and Cognitive Sciences,

University of Allahabad, India

Email: niharika@cbcs.ac.in

Abstract

Previous research suggests that while cognitive abilities decline with age, semantic and verbal knowledge remain stable or may even improve with age. The present study investigated how aging impacts anticipation during comprehension, considering that both language experience and cognitive factors modulates prediction during comprehension. We investigated whether older adults can utilize gender-marked adjectives to predict the target noun during Hindi sentence comprehension. Two visual world paradigm studies (Experiment 1 & 2) were conducted, where young and older adults listened to sentences containing a target word while looking a visual display containing the target object along with three distractors. The sentences consisted of adjectives which were highly associated with the target object. We measured anticipatory gaze towards the target object before it was mentioned in the sentence indexing prediction using adjective. The results from both experiments showed that older adults exhibited anticipatory gaze towards the target noun soon after hearing adjective, which did not differ from that of young adults. The findings provide robust evidence that older adults can effectively use semantic, syntactic or associative information from the adjective to predict the target noun, similar to young adults. The present findings show that older adults can generate prediction using their world knowledge and accumulated language experience throughout their lives.

Key words: Aging, Anticipation, Language comprehension, anticipatory eye movements

Introduction

The process of aging is marked by a gradual decline in cognitive abilities, which include, diminished executive control, processing speed, and overall reduction in memory capacity (Huettig & Janse, 2016; Braver & West, 2008; Raz, 2000; West, 1996). Despite marked decline in various cognitive components, semantic knowledge and vocabulary (i.e. crystallized intelligence) remain resilient or may even be enhanced with aging. This has led to a great deal of research on understanding how aging impacts anticipation during language comprehension, as both language experience and cognitive factors, contribute to anticipation. Previous studies present conflicting evidence regarding prediction in older adults during comprehension (Federmeier et, al.,2010; Dave et. al., 2021; Stine-Morrow, Miller, & Hertzog, 2006; Payne & Stine-Morrow, 2012). There are studies that show a decline in anticipation in older population, however, contrary to this, there are some studies which have found that older adults can generate prediction comparable to younger adults by relying on the rich context and semantic knowledge (Milburn et al., 2023; Payne & Silcox, 2019; Pichora-Fuller, 2008; Stine-Morrow et al., 2006; Lash et al., 2013; Choi et al., 2017). In the present study, we examined whether older adults can use gender-marked adjectives during comprehension of spoken Hindi sentences to predict the target noun in real time using visual world paradigm.

Language experience and anticipation

Anticipation during language comprehension refers to the generation of predictions regarding future elements in a sentence, including words, phrases, or even broader discourse structures. Readers or listeners constantly generate expectations about the likely course of a sentence, drawing from various cues, such as such as thematic roles (Altmann,1999; Altmann & Kamide, 1999), syntactic frames (Chen, Gibson, & Wolf, 2005;Staub & Clifton, 2006), morpho-syntactic structures (Kamide, Scheepers, & Altmann, 2003; Huettig & Brouwer,2015), prosody (Weber, Grice, & Crocker, 2006), linguistic knowledge (Mishra et al. 2012; Mani & Hueittig, 2012), pragmatics, or world knowledge (Kamide, Altman & Scheepers, 2003; Warren & Dickey,

2021; McRae & Matsuki, 2009). As language experience increases, the use of these cues becomes efficient leading to more refined and accurate predictions (Mishra et al. 2012; Cheimariou, Farmer, & Gordon, 2021). Language proficiency, vocabulary size, grammar, and efficient language processing contribute to a person's ability to accurately predict during language comprehension. Previous studies have shown that individuals with better vocabulary knowledge (Fernaldd, Perfors, & Marchman, 2006; Tokildsen et al., 2008) or greater exposure to print, process words more automatically (Cheimariou, Farmer, & Gordon. (2021;). Mani & Hueittig (2012) found that children with higher vocabulary size launched more anticipatory gaze towards the target object when they heard sentences with constraining verb than sentences with non-constraining verbs. Similar findings were replicated with 8 year old children using visual world paradigm, where skilled readers displayed more anticipatory gaze towards the target before spoken onset of the noun in a semantically constraining condition, thus showing language fluency and efficiency contributes to prediction (Mani & Huettig, 2016). Mishra et al. (2012) showed that prediction during comprehension in adults is modulated by different levels of literacy. It was found that individuals with lower literacy were less effective at utilizing adjectives as a cue to predict upcoming spoken linguistic input compared to those with high literacy. The participants were shown a visual arrangement of objects and simultaneously heard sentences with adjectives which were highly constraining towards one of the objects in the display. High literates quickly shifted their gaze towards the object compatible with the adjective before it was mentioned in the sentence, while low literates only did so after hearing the name of the object in the sentence.
Likewise, evidence from the visual world paradigm has demonstrated use of different sources of knowledge as a cue for prediction during sentence comprehension (Altmann & Kamide, 1999; Boland, 2005; Borovsky et al., 2012; Kamide et al., 2003; Mack et al., 2013; Milburn et al., 2016). It has been found that people use world knowledge to predict verb argument. Altman and colleagues (1999) investigated how selectional restriction of verb is used in online prediction of likely theme (object) of a verb using visual world paradigm. Altaman and Kamide (1999) demonstrated that individuals utilize the selectional restriction of verbs (e.g., eat vs. move) to predict the verb-argument. Participants were more likely to launch anticipatory eye movements towards a picture of a cake upon hearing a sentence with constraining (For example, "*The boy will **eat** the….*") compared to when they heard sentences with non constraining verb (For example, *"The boy will **move** the*…."). This shows people use selectional restriction of verb to narrow down the set of plausible objects to follow. Kamide et al., (2003) showed that world knowledge can further refine the

generation of prediction of verb argument. Their findings showed that participants combined world knowledge about the agent (girl vs. man) with the restrictions of the verb to drive predictions about the verb argument. For example, participants gazed more towards the picture of a carousel in the display upon hearing, “*The **girl** will **ride** the*... “, whereas looked more towards the picture of a motor cycle when they heard, “*The **man** will **ride** the*.....”. This shows the participants used a blend of world knowledge and verb selectional restriction for generating predictions. In sum, the evidence suggests that prediction during comprehension is influenced by language experience and world knowledge (Milburn, 2016; Kukona et al., 2016; Magnuson,2019; See Kamide, 2008 for more details).

Anticipation and Aging:

Previous research presents mixed evidence on how anticipation during sentence comprehension is impacted by aging. There are some studies which have shown that older adults have difficulty in generating expectations about upcoming words, thus indicating towards reduced prediction abilities with aging. These findings are consistent with the broader cognitive changes associated with aging, including declines in working memory capacity, processing speed, and inhibitory control, which have a negative impact (Federmeier & Kutas, 2005; Janse & Jesse 2014) on various aspects of cognition, including memory and language processing. For example, working memory plays a crucial part in sentence comprehension and anticipation. High working memory capacity enables individuals to predict better and also helps in resolving prediction errors during sentence processing (Häuser et al., 2017). Working memory serves as an interface for interaction of long term memory, linguistic information and visual attention during language comprehension in a visual context (Huettig, Oliver & Hartsuikar, 2011). Huettig and Jense (2016) did a study using a visual world paradigm where the participants received spoken instructions while viewing four objects, and the articles employed in the sentence were gender-marked in a way that ensured agreement in gender solely with the target. The study used multiple regression analyses to show that both verbal and spatial working memory influence language-mediated anticipatory eye movements. The finding suggested that enhanced working memory abilities and faster processing speed predicted anticipatory eye movements. In sentence reading, working memory can influence regression probability, and processing speed influences the go-past time in the eye-tracking task. These factors appeared to significantly impact general language processing and prediction in particular (Cheimariou. S, 2016). So any deficit in cognitive factors could hinder the cognitive resources necessary for generating and maintaining predictions.

In a sentence reading study by Kliegl et al. (2004) indicate that both, young and older adults were influenced by predictability by the context, but the way it affected them differed. Younger adults tended to skip words that were highly predictable, whereas older adults did not exhibit the same predictability-related effect in skipping rates. Instead, older adults made more fixations on unpredictable words and fewer fixations on highly predictable ones. Consequently, both age groups read highly predictable words more swiftly than less predictable ones, but the advantage in reading for predictable words was manifested differently depending on age. In some contexts, older adults are able to use the cue to process the upcoming input, but when cognitive load is increased, they fail to perform sentence processing like younger adults (Hauser et al, 2017). In a recent research by Fernandez et al., (2020), they tested the impact of speech rate on anticipatory eye movement of young and old adults during spoken sentence comprehension. They varied speech rates (3.5, 4.5, 5.5 and 6.0 syllables per second) of the presented sentences. The results showed that older adults exhibit anticipatory behaviour akin to that of younger adults and even display anticipatory gaze towards the target at a slower speech rate of 3.5 to 4.5 syllables per second but not with rapid speech rates of 5.5 and 6.0 syllables per seconds. Further, evidence form ERP studies have shown that older adults exhibited a smaller and delayed N400 as compared to young adults when processing highly constraining sentences with unexpected endings. This reduced N400 in older adults indicate failure of prediction of the upcoming target word (Federmeier et al., 2007; Wlotko et al. (2010; DeLong et al., 2012; Federmeier & Kutas, 2005; Federmeier et al., 2010).

In contrast, alternative research proposes that while older adults experience age-related cognitive decline, their ability to generate predictions remains intact. Older adults can rely on well-established world knowledge, simpler syntactic cues, or broader lexical heuristics to formulate predictions that differ in nature from those of younger adults (Cheimariou. S, 2016, Milburn, 2021). It is argued that crystallized knowledge, including world knowledge remains well preserved in older adults despite cognitive decline (Horn & Cattell, 1967). Previous studies have shown that older adults compensate for the effects of cognitive decline by relying on their well preserved world knowledge for prediction during comprehension (Milburn et. al., 2023; Pichora-Fuller, 2008; Stine-Morrow et al., 2006). Milburn et. al., (2023), findings provide clear evidence that older adults are able to exploit the world knowledge to activate upcoming verb arguments, particularly when that world knowledge is cued by semantically-rich verb + argument combinations

(e.g., Borovsky et al., 2012; Kamide et al.,2003). The older participants showed more pronounced prediction as compared to young adults when they heard sentences with agent + constraining verb(*The dog will drink*...) than when they predicted solely on the basis of constraining verb(*Someone will drink*...). Stronger prediction in older adults in the agent + verb condition shows that older adults were able to take advantage of semantic/world knowledge better than younger adults which resulted in more anticipatory gaze towards the target for the older adults. This is similar to visual-world findings reported by Baltaretu and Chambers (2018) which found that
older adults exhibited anticipatory fixations to an upcoming spoken input as quickly as young adults' did. This aligns with the idea that older adults can effectively exploit semantic context while language comprehension (Pichora-Fuller, 2008; Stine-Morrow et al., 2006), demonstrating comparable performance to younger adults when rich semantic context is available (Lash et al., 2013; Payne & Silcox, 2019). It is quite possible that lifelong linguistic experience in older adults makes them more skilled language users, enabling them to predict upcoming information better than young adults. Nevertheless, this advantage is counterbalanced by age-related cognitive declines.

The Present Study

Previous studies on prediction in older adults primarily focused on anticipation using rich semantic context or verb-argument structures. However, it requires further investigation whether older adults can rely upon their world knowledge to predict target word utilizing adjectives and grammatical gender information as cues for prediction. Use of gender-marked adjective for prediction requires knowledge of morpho-syntactic rules, as well as semantic/world knowledge about the noun and adjective associations. The frequent co-occurrence of certain adjectives and nouns in everyday language (for example: soft fur; green leaves) contributes to our semantic and world knowledge (Fyshe et al., 2019). Previous investigations with young adults indicate use of gender–marked adjectives to anticipate subsequent noun referent. Gussow et al. (2019) explored the role of gender-marked adjectives in adjusting lexical predictions during Spanish sentence comprehension. It was found that participants gaze was constrained by the gender marked adjectives such that participants looked towards the gender marked noun that matched with the gender marked adjectives. Similarly, in Hindi language, adjectives are gender marked (e.g. *chota (small(masculine) and choti(small, feminine))* matching with the modified noun's gender. Using a visual world paradigm Mishra et al.(2012) presented spoken Hindi sentences, with gender-marked adjectives followed by the particle "wala/wali" and a noun (e.g., "*Abhi aap ek unvha wala darwaza* *dekhengey*" (Right now, you are going to see a tall door). It was found that young literates launched more anticipatory gaze towards the noun matching with the gender marked adjective. Notably, the study found that adjectives were the sole predictor for the noun, as the sentences themselves were contextually neutral. Taken together, these findings illustrate the use of gender marked adjectives for anticipation.

In current study, we conducted two experiments to investigate the use of gender-marked adjectives as a cue for anticipation during spoken sentence comprehension in Hindi, comparing young and older adults using visual world paradigm. In both the experiments, we used the same sentences from the study by Mishra et al. (2012), which consisted of gender-marked adjective as a cue to predict the target noun. The visual display was consisted of a target object along with three distarctor objects. The spoken sentences offered no other semantic cues to predict the noun except for the adjective (Abhi aap ek nukili waali sui dekhengey/Now you will see a sharp needle), which was highly associated with the target noun. The two experiments conducted only differed in the duration of the display preview time. It was hypothesized that if older adults can use adjectives as a cue to predict upcoming target noun, both young and older adults would demonstrate comparable anticipatory looks to the noun. Conversely, if older adults cannot utilize adjectives to predict the target noun, they will exhibit fewer or no anticipatory eye movements towards the noun upon hearing the adjective compared to young adults.

Methods

Participants

Twenty-nine young adults (20 to 30 years, mean=22.62, SD=2.22) and twenty-four older adults (55 to 75 years, mean=63.08, SD=5.51) participated in the study. All participants had normal or corrected-to-normal vision and no history of speech-language, hearing, or neuropsychological disorders. Participants self-identified as native Hindi speakers and had at least 15 years of formal education. To exclude the presence of unreported memory or any other cognitive disorders, participants were given the Mini-Mental State Exam (MMSE: Folstein, Folstein & McHugh, 1975). All participants achieved a score of 28 or higher on the MMSE, indicating cognitive health (young adult’s mean=29.03, SD= 0.86; old adult’s mean=29.12, SD=0.90). These scores are above the lower-quartile cutoff scores for healthy older adults (Bleecker et al., 1988). The ethics committee of University of Allahabad approved the study, and informed consent was obtained from all participants.

Table (1): Participants data for Experiment 1

	AGE		MMSE		Raven's Progressive Matrices		Digit span		Hindi Proficiency		Hindi Exposure	
	old	**young**	**old**	**young**	**old**	**young**	**old**	**young**	**old**	**young**	**old**	**young**
No. of participants	24	29	24	29	24	29	24	29	24	29	24	29
Mean	63.083	22.621	29.125	29.034	44.833	51.276	17.833	20.759	9.530	8.793	74.343	51.099
Std. Deviation	5.516	2.227	0.900	0.865	10.231	4.543	3.784	2.760	0.468	0.906	19.766	16.537
Minimum	55.000	20.000	28.000	28.000	25.000	42.000	12.000	14.000	8.571	6.286	36.923	26.154
Maximum	75.000	29.000	30.000	30.000	59.000	58.000	30.000	26.000	10.000	10.000	100.000	91.538

Materials and Stimulus Presentation

The experiment consisted of presentation of 58 visual displays (28 experimental and 30 fillers), each consisting of four visual objects (one target and three distractors) paired with a spoken sentence. Each experimental sentence consisted of a lead-in phrase (“abhi aap ek”/Now you will) followed by an adjective (e.g., 'nukili', sharp), then the particle ('wala'/'wali') and a noun (e.g., 'Sui', needle)(e.g. “Abhi aap ek nukili waali sui dekhengey”/Now you will see a sharp needle). The adjective (e.g., 'nukili’ sharp) was associated with only one object in the display. Similarly, the grammatical gender of the adjective agreed only with the target object, not with the distractor objects in the same display. The filler sentences were without adjectives (eg. “Abhi aap ek kitab dekhege”/ Now you see a book).

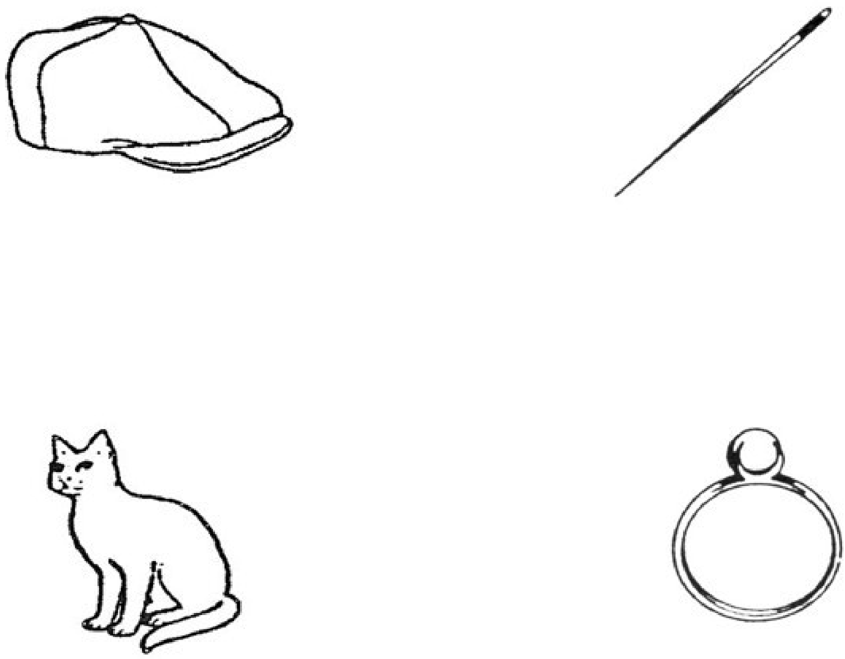

Fig 1: Example display, where the auditory sentence was “abhi aap ek nukili wali sui dekhege”.

A rating study was conducted for sentences and pictures to select the most suitable stimuli for the experiment. For sentence rating, 20 young Hindi-speaking adults from the University of Allahabad participated; none participated in the main study. Eighty sentences were provided for the rating, 40 sentences with adjectives and 40 filler sentences. For sentences with adjectives, participants rated them based on adjective-noun association and understandability of the sentences on a 7-point Likert scale. Twenty-eight experimental sentences and 30 filler sentences with an average rating of more than 6 were selected for the main study. All the sentences were recorded by a female native Hindi speaker. Visual displays used in the experiment (Figure 1) consisted of line drawings of the target object (e.g., sui) and three unrelated distractors. All visual stimuli were frequent and common objects known to both young and old participant groups.

Procedure

Participants were seated at a comfortable distance from a 24-inch monitor. A central fixation point appeared on the screen for 750 ms, followed by a blank screen for 500 ms. then four pictures appeared on the screen. The positions of the pictures were randomized across four fixed positions of a (virtual) grid on every trial. The auditory sentence was presented 1500 ms from the display onset. Participants have to perform a 'look and listen' task (Altmann & Kamide, 1999).Participants' eyes were tracked using an Eyelink 1000 tracker (SR Research Ltd., Toronto, Ontario, Canada) with a sampling rate of 1000Hz. The study utilized the Experiment Builder software (SR Research Ltd., Toronto, Ontario, Canada) to design and administer the experiment. Participants observed stimuli with both eyes on a monitor situated around 60 cm from them, and head movements were restricted by using forehead and chin rests. Following an explanation of the experiment's structure, the eye tracker was calibrated using a 9-point fixation stimulus to ensure precise and accurate tracking of the eyes across the entire display screen

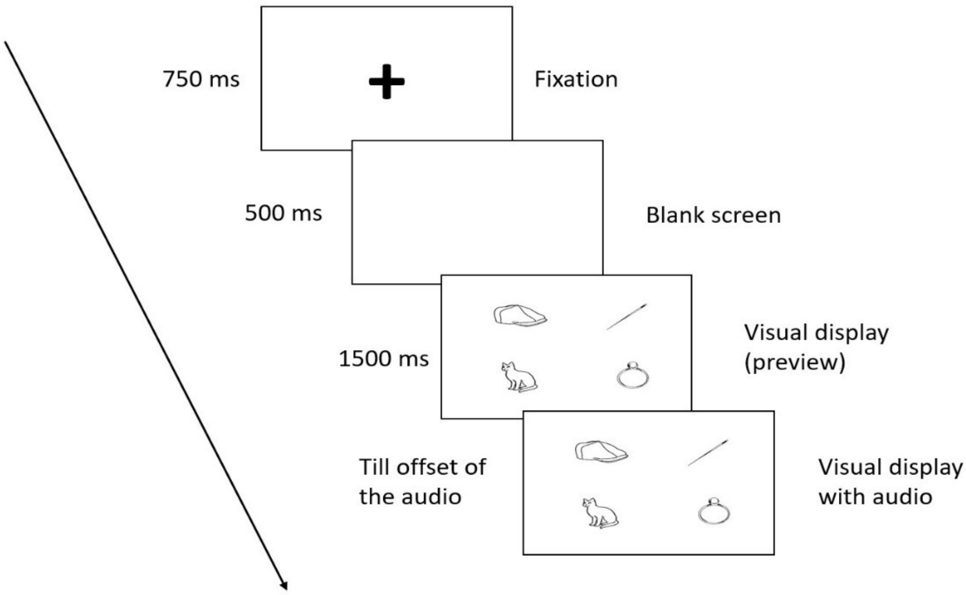

Fig 2: Trial structure for Experiment 1.

Data coding procedure

The information from the right eye of each participant was examined and categorized based on fixations, saccades, and blinks. The temporal aspects of fixations were determined in relation to the commencement of the adjective in the spoken utterance. Fixations were classified according to whether they focused on the target picture or unrelated distractor pictures.

Results

Figure 3 displays a time-course graph illustrating the fixation proportion to the target object or averaged distractors for young and old Adults. The curves on the graph are synchronized with the acoustic onset of the spoken adjective, and the average noun onset was 1240ms (approx.). The x-axis represents time in milliseconds from the acoustic onset of spoken adjectives. Each data point on the graph represents the proportion of trials with a fixation at that specific time point (Huettig & Altmann, 2005). As we can see in Figure 3, participants start to shift their eye gaze towards the target (noun) well before acoustic onset. This is because they can extract information about the upcoming input from the adjective (e.g., ‘nukili wali’) and use that information to generate predictions about the upcoming noun (‘sui’), which helps them shift their eye gaze towards the target.

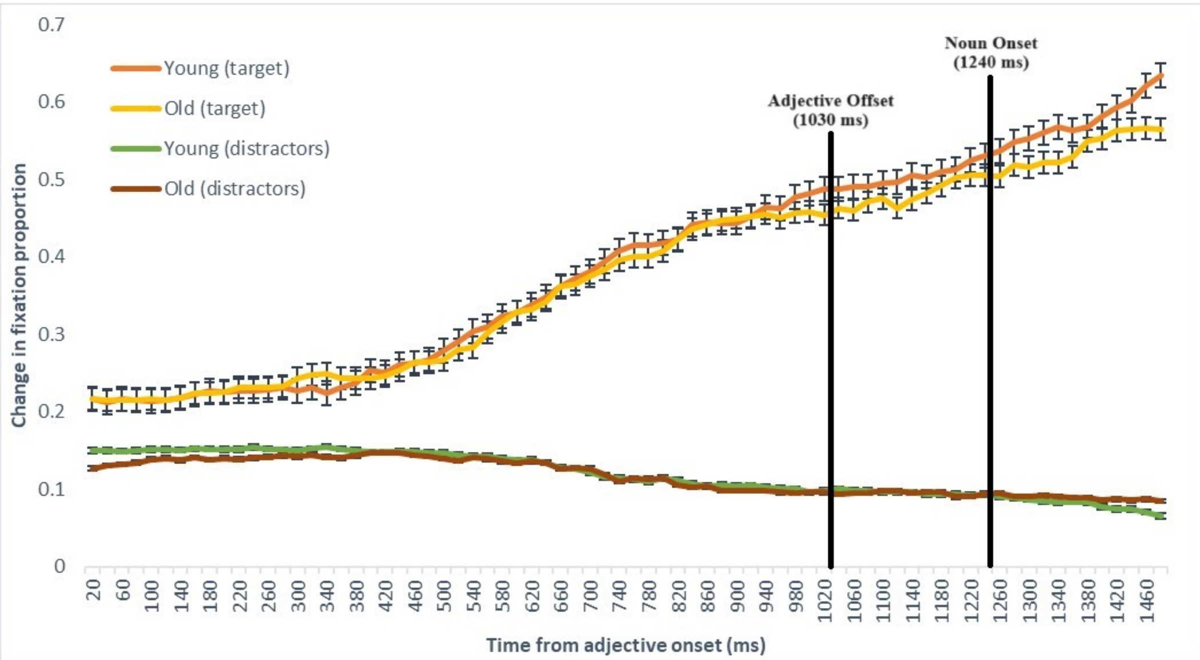

Figure 3: Changes in fixation proportions on the target objects and (averaged) unrelated distractor objects for young and old adults for experiment 1.

For the analysis, four time-windows were pre-determined. For the first time-window (Baseline (0-200 ms) covered the time interval starting from the onset of adjective to 200 ms after. The second time-window (Baseline offset-Adjective offset) covered the period after 200 ms from the adjective onset to offset of the adjective. The third time-window (Adjective offset-Noun onset) spanned the interval between adjective offset and Noun onset, and the fourth time-window (Noun) covered the duration of noun. Proportions of fixation were calculated for each trial, taking into account the specific starting (for example, at the onset of the noun) and ending points (for example, at the offset of the noun) for that particular trial. To compare proportion of looks for the target and distractor images for each time-window we calculated the ratio between the proportion of fixations to the target image and the sum of the proportions of fixations towards the target and the distractor images together:

target-to-distractor ratio= (looks to target)/(looks to target+looks to distractor)

To calculate ratios without encountering undefined expressions due to instances where neither the target nor the distractors received any looks, a tiny constant of 0.00000001 was added to each observation (the number of glances at an image per subject for each item in every time window). If the ratio exceeds 0.5, it signifies that the expected image garnered more than half of the total looks directed at both the expected and alternative images combined (refer to Dahan & Tanenhaus, 2005; Huettig & McQueen, 2007; McQueen & Huettig, 2012).

For statistical analysis, the ratios were subjected to a logit transformation, ensuring that a ratio of 0.5, which indicates equal probabilities of fixating on the expected versus the alternative image, was mapped to a value of 0 in the transformed dataset. Linear mixed-effects models were estimated utilizing the lme4 package (Bates, Maechler, & Dai, 2009) in the R programming environment (R Core Team, 2023). The model with a formula: fixation ~ time_window * group + (1 | Participants) + (1 | trial) was used .This implies that fixation is modeled as a function of the effects of time window, group, and their interaction, with random intercepts for participants and trial.

The results showed comparable anticipation effect for both the age groups on the target-to-distractor ratio, as model showed that the young group's fixation did not significantly differ from the older group at the reference level (B=-1.402, SE=1.020, t=-1.374, p=0.173). Coefficients for the time-windows indicate notable positive impact, suggesting heightened fixation during various time intervals compared to the baseline. The time-windows: Baseline offset-Adjective offset (B=2.376, SE=0.581, t=4.09, p=<0.0001), Adjective offset-Noun onset (B=6.489, SE=0.581, t=-11.17, p=<0.0001), and Noun (B=-7.685, SE=0.581, *t*=-13.228, *p*=<0.0001) were significantly higher than the Baseline (0-200ms) window.

Within group comparison across time windows also suggested a significant increase in the fixation proportion for the target. For the young participants, the target-to-distractor ratio during the Baseline offset-Adjective offset (Mean difference= -3.555, SE= 0.528, Z ratio= -6.737, *p*<.0001), Adjective offset-Noun onset (Mean difference= -8.307, SE= 0.528, Z ratio= -15.744, *p*<.0001), and Noun (Mean difference= -11.545, SE= 0.528, Z ratio= -21.88, *p*<.0001) time-windows significantly differed from the Baseline (0-200 ms) time-window. Similarly, for older adults, the target-to-distractor ratio during the Baseline offset-Adjective-offset (Mean difference= -2.376, SE= 0.581, Z ratio= -4.09, *p*<.0001), Adjective offset - Noun onset (Mean difference= -6.489, SE= 0.581, Z ratio= -11.17, *p*<.0001), and Noun (Mean difference= -7.685, SE= 0.581, Z ratio= -13.228, *p*<.0001) time-windows significantly differed from the baseline time-window.

Between group comparisons of each time-windows: Baseline (Mean difference= 1.402, SE= 1.021, Z ratio= 1.374, *p*= 0.869), Baseline offset – Adjective offset (Mean difference= 0.224, SE= 1.021, Z ratio= 0.219, *p*= 1), Adjective offset - Noun onset (Mean difference= -0.416, SE= 1.021, Z ratio= -0.408, *p*= 0.999), and Noun (Mean difference= -2.458, SE= 1.021, Z ratio= -2.408, *p*= 0.237); showed no significant difference. This result suggests there was no statistical difference between both the groups, as both young and old adults were able to use the information extracted at adjectives to guide their anticipatory eye gaze towards the target image well before the unfolding of the target(noun) word (Cheimariou. S, 2016, Milburn et. al., 2023, Baltaretu and Chambers (2018).

Overall, the results indicate that both young and older adults were able to use the adjective to predict the upcoming noun; further older adults did not differ in launching their anticipatory gaze towards the object depicting the noun in the sentence. This shows that older adults could use the predictive cues as efficiently and robustly as the young participants.

Experiment 2:

Huettig and Guerra (2019), using visual world paradigm showed that reducing the display preview time makes prediction challenging. Experiment 2 was designed to investigate how both groups would perform when the time is given to process the visual information is reduced. In the visual world paradigm, when participants see the visual display, they activate visual, phonological, and semantic representations of the objects in the display, which are maintained in their working memory (Heuttig, Mishra, & Olivers, 2012; Huettig & McQueen, 2007). During comprehension of spoken sentences, the match between the predicted target item and its representations in working memory drives participants' gaze towards the visual object corresponding to the predicted target. However, reducing display time can hamper the activation of these representations, making prediction difficult. Experiment 2 was same as experiment 1 except for the visual preview duration. In experiment 1, participants had a preview display of 1500 ms before the acoustic onset of the sentence, whereas in the Experiment 2, it was reduced to 500ms. It was hypothesized that short preview duration would hamper anticipation for both the groups, but older would be affected the most.

Methods

Participants

Twenty-four young adults (20 to 30 years, mean=22.41, SD=2.35) participated in the experiment. All the participants were current residents of Prayagraj (UP, India) and native Hindi speakers, and college-going students. All the participants had normal vision, and none had any known hearing problems. Twenty-four old adults (55 to 75 years, mean=62.79, SD=5.57) from Prayagraj, with self-reported normal or corrected-to-normal vision and without a history of speech-language, hearing, or neuropsychological disorders participated in the experiment. Participants self-identified as native Hindi speakers and had at least 15 years of formal education. In order to exclude the presence of unreported memory or other cognitive disorders, participants were given the Mini-Mental State Exam (MMSE: Folstein, Folstein & McHugh, 1975). All participants scored 28 or better on the MMSE (young adult's mean=29.04, SD= 0.90; old adult's mean=28.95, SD=0.85), which is above the lower-quartile cutoff scores for healthy older adults (Bleecker et al., 1988). The ethics committee of University of Allahabad approved the study, and informed consent was obtained from all participants.

Table (2): Participants data for Experiment 2

	AGE		**MMSE**		**Raven's Progressive Matrices**		**Digit span**		**Hindi Proficiency**		**Hindi Exposure**	
	old	**young**	**old**	**young**	**old**	**young**	**old**	**young**	**old**	**young**	**old**	**young**
No. of Participants	24	24	24	24	24	24	24	24	24	24	24	24

Table (2): Participants data for Experiment 2

	AGE		MMSE		Raven's Progressive Matrices		Digit span		Hindi Proficiency		Hindi Exposure	
	old	**young**	**old**	**young**	**old**	**young**	**old**	**young**	**old**	**young**	**old**	**young**
Mean	62.792	22.417	28.958	29.042	46.333	50.917	18.125	20.542	9.482	8.804	75.515	51.365
Std. Deviation	5.572	2.358	0.859	0.908	8.218	4.781	3.768	2.889	0.461	0.973	16.721	17.235
Minimum	54.000	20.000	28.000	28.000	28.000	42.000	12.000	14.000	8.571	6.286	36.923	26.154
Maximum	73.000	29.000	30.000	30.000	59.000	58.000	30.000	26.000	10.000	10.000	98.750	91.538

Procedure

Participants were seated at a comfortable distance from a 24-inch monitor. A central fixation point appeared on the screen for 750 ms, followed by a blank screen for 500 ms. then four pictures appeared on the screen. The positions of the pictures were randomized across four fixed positions of a (virtual) grid on every trial. The auditory sentence was presented 500 ms from the display onset. Participants have to perform a 'look and listen' task (Altmann & Kamide, 1999).

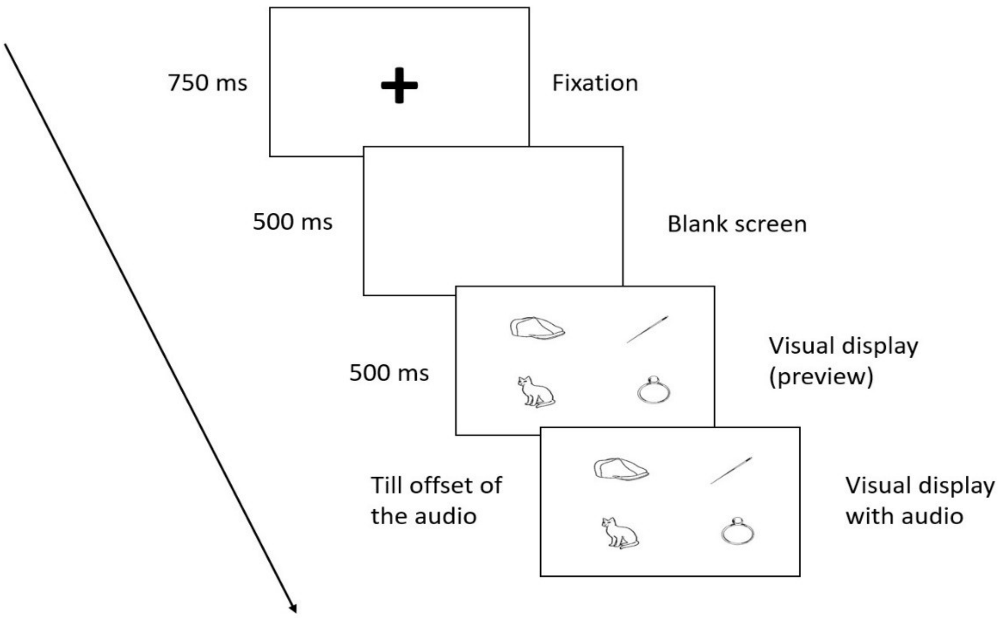

Fig 4: Trial structure for Experiment 2

Result

The outcomes are displayed in a manner consistent with the approach used in experiment 1. Figure 5 shows a time-course graph illustrating the fixation proportion to the target object and averaged distractors for young and old adults. The curves on the graph are synchronized with the acoustic onset of the spoken adjective. The x-axis represents time in milliseconds from the acoustic onset of spoken adjectives. As we can see in Figure 5, like Experiment 1, participants in Experiment 2 also start shifting their eye gaze towards the target (noun) well before acoustic onset.

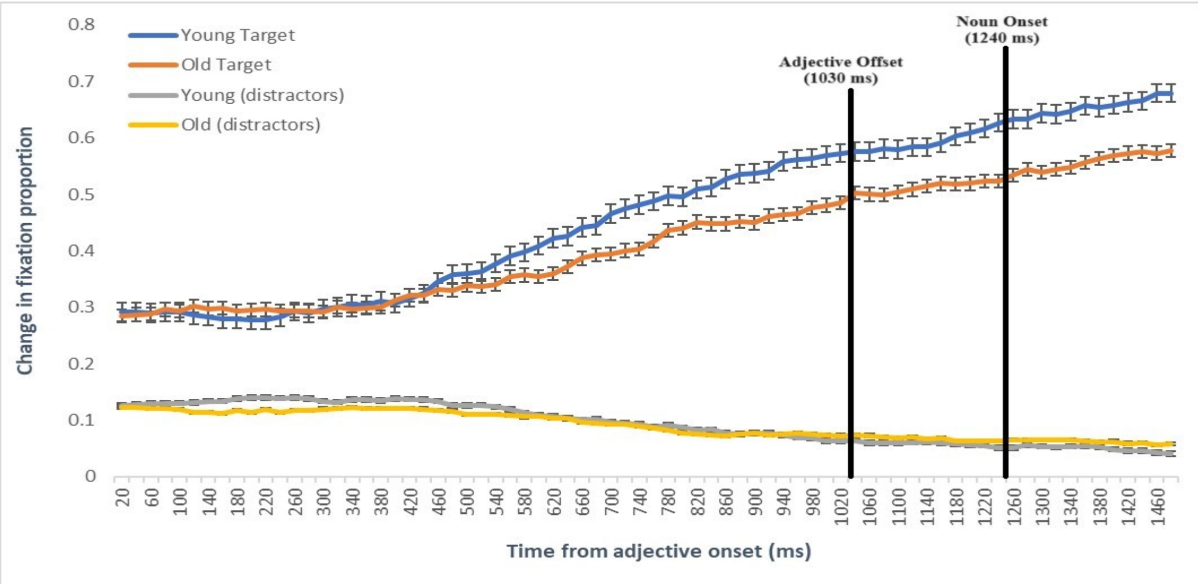

Figure 5: Changes in fixation proportions on the target objects and (averaged) unrelated distractor objects for young and old adults

A comparable anticipation effect was found for both groups on the target-to-distractor ratio, as model showed that the young group's fixation ratio did not differ significantly from the older group at the reference level (B=-0.878, SE=1.129, *t*=-0.778, *p*=0.439). The subsequent time-windows: Baseline offset-Adjective offset (B=2.528, SE=0.564, *t*=4.483, *p*=<0.0001), Adjective offset-Noun onset (B=6.215, SE=0.564, *t*=-11.02, *p*=<0.0001), and Noun (B=-7.450, SE=0.564, *t*=-13.209, *p*=<0.0001) were significantly different from the Baseline (0-200ms) window.

Within group comparisons across time windows also suggested a significant increase in the fixation proportion for the target. For the young participants, the target-to-distractor ratio during the Baseline offset-Adjective offset (Mean difference= -3.154, SE= 0.565, *Z* ratio=

-5.584, *p*<0.0001), Adjective offset-Noun onset (Mean difference= -9.037, SE= 0.565, *Z* ratio= -15.998, *p*<0.0001), and Noun (Mean difference= -10.877, SE= 0.565, *Z* ratio= -19.256, *p*<0.0001) time-windows were significantly differed from Baseline (0-200 ms) time-window. Similarly, for the older adults, the target-to-distractor ratio of Baseline offset-Adjective_offset (Mean difference= -2.529, SE= 0.564, *Z* ratio= -4.483, *p*=0.0002), Adjective offset - Noun onset (Mean difference= -6.215, SE= 0.564, *Z* ratio= -11.02, *p*=0.0001), and Noun (Mean difference= -7.45, SE= 0.565, *Z* ratio= -13.209, *p*<0.0001) time-windows significantly differed from the baseline time-window.

Between group comparison of each time-windows: Baseline (Mean difference= 0.879, SE= 1.13, *Z* ratio= 0.778, *p*= 0.994), Baseline offset – Adjective offset (Mean difference= 0.253, SE= 1.13, *Z* ratio= 0.224, *p*= 1), Adjective offset - Noun onset (Mean difference= -1.943, SE= 1.13, *Z* ratio= -1.72, *p*= 0.674), and Noun (Mean difference= -2.548, SE= 1.13, *Z* ratio= -2.255, *p*= 0.318) showed no significant difference. This implies that the data did not provide evidence of differences between groups in the specified time intervals.

The results of the Experiment 2 replicate the pattern obtained in the Experiment 1, thus providing evidence of comparable prediction abilities in the older adults compared to the young adults. Further, it shows that both groups can predict even with shorter preview duration.

Discussion:

The main aim of the study was to investigate whether older adults can generate prediction during spoken sentence comprehension using gender-marked adjectives in Hindi. To examine this, two experiments were conducted where young and older adults were presented with sentences consisting of gender-marked adjectives related to the upcoming noun in the spoken sentence. Participants' anticipatory eye movements were tracked towards an array of images depicting the target (suii $_{fem}$ (needle)) that matched with gender-marked adjective (nukili waali) along with other three unrelated distractors (all feminie) while they listened to the spoken sentences.

The results indicate that soon after the onset of the adjective followed by the particle *waala/waali*, both young and older adults launched more anticipatory gaze towards the target object consistent with the adjective, compared to the distractors. This was well evident through a higher target-to-distractor ratio in both the Baseline offset-Adjective offset and the Adjective offset-Noun onset time-windows for both the age groups. A marked rise in the target-to-distractor ratio for the Adjective offset-Noun onset window compared to the Baseline and

Baseline offset-Adjective offset windows for both the groups indicates more anticipatory fixations towards the target object. This suggests that both age groups, soon after hearing the adjective, were able to pre-activate the noun compatible with adjective, thus providing clear evidence that both young and older adults effectively used gender-marked adjectives to predict the upcoming noun. This is consistent with other studies showing use of grammatical cues (Altman & Kamide, 2007), grammatical gender (Gussow, Kapnoula, & Molinaro, 2019), adjectives (Mishra et al, 2012, Gussow et al., 2019) for prediction previously found with young adults. The present study extends these findings with older adults suggesting older adults too can use adjectives to make accurate and rapid predictions.

The between group comparisons showed the target-to distractor ratio for the Baseline offset-Adjective offset and the Adjective offset to Noun onset time-windows for the older adults were comparable to the target-to-distractor ratio for the young adults; showing older adults did not differ from young adults in their anticipatory gaze to a target object. This suggests that older adults robustly predicted the upcoming noun based on the gender-marked adjective. Participants fixating the target before the mention of noun were observed in both longer (Experiment 1) and shorter (Experiment 2) display preview durations, thus confirming our hypothesis. The current findings provide clear evidence that prediction during comprehension is not hampered with aging. This aligns with previous studies using visual-world findings indicating that older adults can anticipate likely upcoming target as quickly and effectively as young adults (Baltaretu and Chambers, 2018; Milburn et. al 2021, Huetting & Janse, 2015). The present findings shows that older adults relied on their world knowledge about the association between adjectives and noun to predict the target noun.

Our findings is line with previous findings indicating crystallized intelligence, including lexical semantic knowledge remains quite stable with advancing age. Previous studies have shown that older adults, like their younger counterparts matched for verbal abilities, tend to generate similar word associates and category exemplars (Burke & Peters, 1986; Howard, 1980).The gender-marked adjectives used in our study were highly associated with the target nouns. For example, the adjective "*nukili*"(sharp (feminie)) was highly associated with the target noun *'suii'*(needle(feminie)), but not associated with the three unrelated distracters (eg. Topi, billi, angoothi). Older adults relied on either associative or/and syntactic information (Bar, 2007) for prediction as the adjectives were highly constraining towards the target noun. This shows that older adults can use world knowledge about the association between adjective and noun as well as syntactic knowledge such as gender and case agreement between adjective and noun for anticipation. This provides evidence that older adults can engage in prediction relying upon their resilient crystallized intelligence and semantic knowledge (Horn & cattell, 1967; Milburn et al., 2016; 2023).

According to the language experience driven account of anticipation in language, it is expected that prediction abilities increase with linguistic experiences (Mishra et. al., 2012). Following this theory, one would predict higher prediction skills in older adults compared to young adults. However, our study revealed comparable prediction abilities in both young and old adults. It is plausible that semantic, grammatical knowledge and conceptual associations strengthen with age due to years of language experience, enhancing prediction skills in older adults. However, cognitive decline associated with aging may hamper this enhancement. Consequently, the expected increase in prediction skill may not be evident in anticipatory eye movements.

Previous studies investigating anticipation in older adults have shown that older adults can predict when provided with rich semantic context(Kamide et al., 2003; Milburn et al., 2016, Lash et al., 2013; Payne & Silcox, 2019; Pichora-Fuller, 2008; Stine- Morrow et al., 2006; Wingfield & Stine-Morrow, 2000). Milburn et. al (2021) found that older adults can effectively take advantage of their preserved crystallized intelligence and world knowledge in prediction during sentence comprehension. They found that the older participants showed more pronounced anticipatory fixations to the target than younger adults when presented with semantically rich-verb + argument combinations (e.g., “The dog will drink…”.) compared to when only a verb argument was used to predict(e.g., “Someone will drink the milk….”) the target. While their study strongly supported preserved prediction in older adults, it also revealed the critical role of semantically rich context in generating robust predictions during sentence comprehension in older adults (Payne & Silcox, 2019; Pichora-Fuller, 2008; Stine- Morrow et al., 2006; Wingfield & Stine-Morrow, 2000). However, in our study, adjective was the sole predictor of the noun, as the sentence itself was contextually and semantically neutral (e.g., “*Abhi aap ek nulili (adjective) waali suii(target)dekengey”*/ Now you will see a sharp needle). Unlike Milburn et. al’s(2021) study, where prediction is built up over the course of sentence, making use of agent + verb to predict the noun(e.g., object argument), the cue for prediction in our study was relatively local or adjacent to the target noun. It seems that both the age groups strategically exploited the only predictive cue available in the sentence for prediction, as only one object in the display matched the adjective. This indicates that older adults can predict upcoming nouns based on gender-marked adjectives in Hindi, marking a departure from previous studies focusing on global, discourse, or rich semantic contexts for prediction in older adults. This study showcases anticipation using local, lexical context in the older population by relying upon the adjective and its grammatical gender. This is consistent with the Huettig & Janse (2015) findings showing use of local article gender as a cue for prediction of noun, which remains unchanged with age.

The present findings contradicts accounts proposing language-specific decline in predictive processing in healthy cognitive aging (DeLong et al., 2012; Wlotko et al., 2010) and other studies where negative effect of aging on prediction in older adults was found (Federmeier & Kutas, 2005; Janse & Jesse 2014). This discrepancy in the results could be attributed to several differences in our study and others. Firstly, the age range for the older group in our study was 55-75 years, with a mean of 63.08 years, which is less than the age ranges used in other studies. Most of the older participants (N=18) fell within the 55-65 age range, while only 6 older participants were between 66-75 age range. It is quite possible that recruitment of relatively less old population in our study may have influenced the findings of our study, and including older adults over 70 years could yield different results.

Secondly, the sentences used in study were quite simple. Use of contextual information for prediction is linked with working memory capacity (Federmeier et al., 2005).While longer sentences can offer multiple progressive cues which aids prediction, they also impose processing cost. Use of simple sentences in our study, with a cue adjacent to the target noun, imposed minimal load on the working memory during meaning integration, leaving capacity relatively free to engage in prediction. In the present study, the older adults' mean WM score (out of 30) was 17.8 while for younger adults it was 20.5. It is quite possible that older adults despite have low WM scores could do engage into prediction as the sentences were quite simple.

In the Experiment 2, we examined whether prediction in older adults is dependent upon extended preview duration of visual display presentations. We hypothesized that longer preview duration is necessary for activation of potential target object, and reducing this duration may hinder prediction. The preview duration was reduced to 500ms, and it was expected that it would result in either no or reduced prediction, particularly affecting the older group. The results from the Experiment 2 showed slightly smaller anticipatory eye movements towards the target object following adjective in the older participants compared to the young adults, however, this difference was not significant for any of the time-windows. Surprisingly, the results from the

Experiment 2 contradicted our hypothesis, suggesting that both the groups could activate the target object despite shorter visual display duration. Huettig and Guerra (2019) found that reducing preview duration affected prediction only in the normal speech rate condition, not for slow speech rate condition. In our study the sentences were presented at slower pace, just like any other visual world paradigm study, which were slightly longer than natural speech, may have contributed to the prediction observed in both the groups. The average duration of the sentences used in our was 4416.6 ms(SD= 251.35) which is bit longer than the normal pace at which such short sentences are spoken in a naturalistic settings. While we did not explicitly examined prediction using sentences with normal speech rate, it is plausible that employing one could have resulted in a smaller prediction effect, especially for the older adults. Even if the prediction happened because of the slower speech rate in our study, it still indicates that older adults demonstrate prediction comparable to the young adults, even with shorter preview duration. The present study clearly shows that older adults are capable of activating the representations which is utilized for prediction.

Conclusions

The current study provides a robust evidence that older adults can generate prediction using gender marked adjectives, which indicates towards utilization of their world knowledge and morpho-syntactic knowledge during language comprehension (Milburn et al.,2021; Lash et al., 2013; Payne & Silcox, 2019. The present findings show positive influence of life long experience with language on prediction which was evidenced by the comparable anticipatory gaze towards the target object in young and older adults .Further, it shows that utilization of their world knowledge in older adults doesn’t remain restricted to generation of verb-argument predictions but it also extends to prediction of nouns using adjective noun agreement knowledge. This further strengthens previous findings that language experience, exposure, and world knowledge influence prediction during comprehension (Mishra et al.,2012; Milburn et al.,2021; Fernaldd, Perfors, & Marchman, 2006; Tokildsen et al., 2008).

Acknowledgements:

This work was supported by a Cognitive Science Research Initiative grant to Niharika Singh and FIST (Fund for Improvement of S&T Infrastructure) grant to the Centre by the Department of Science and Technology, India.

Data availability statement:

The data supporting the findings of this study is available in “Figshare”. The data can be accessed through the given link, http://doi.org/10.6084/m9.figshare.26186534

Declaration of Conflict of Interest

The authors declare there is no conflict of interest.

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Appendix:

*Table (3): Results of linear mixed effect model (model formula: fixation ~ time_window * group + (1 | Participants) + (1 | trial) for Experiment 1.*

Fixed effects	**Estimate**	**Std. Error**	***t***	***p***
Intercept	-2.4469	0.9926	-2.465	0.0156
Timewindow Baseline_offset-Adjective_offset	2.3764	0.581	4.09	<0.0001
Timewindow Between_Adjective-Noun	6.4893	0.581	11.17	<0.0001
Timewindow Noun	7.6853	0.581	13.228	<0.0001
Group Young	-1.402	1.0207	-1.374	0.1732
Timewindow Baseline_offset-Adjective_offset : Group Young	1.1783	0.7848	1.501	0.1333
Timewindow Between_Adjective-Noun : Group Young	1.8181	0.7848	2.317	0.0206
TimewindowNoun : Group Young	3.8599	0.7848	4.918	<0.0001

Table (4): Contrast result for Experiment 1

Contrast	**estimate**	**SE**	**z.ratio**	**p.value**
(Baseline(0-200) Old) - (Baseline_offset-Adjective_offset Old)	-2.376	0.581	-4.09	0.0011
(Baseline(0-200) Old) - (Between_Adjective-Noun Old)	-6.489	0.581	-11.17	<.0001
(Baseline(0-200) Old) - Noun Old	-7.685	0.581	-13.228	<.0001
(Baseline(0-200) Old) - (Baseline(0-200) Young)	1.402	1.021	1.374	0.8694
(Baseline(0-200) Old) - (Baseline_offset-Adjective_offset Young)	-2.153	1.021	-2.109	0.4089

(Baseline(0-200) Old) - (Between_Adjective-Noun Young)	-6.905	1.021	-6.765	<.0001
(Baseline(0-200) Old) - Noun Young	-10.143	1.021	-9.937	<.0001
(Baseline_offset-Adjective_offset Old) - (Between_Adjective-Noun Old)	-4.113	0.581	-7.079	<.0001
(Baseline_offset-Adjective_offset Old) - Noun Old	-5.309	0.581	-9.138	<.0001
(Baseline_offset-Adjective_offset Old) - (Baseline(0-200) Young)	3.778	1.021	3.702	0.0053
(Baseline_offset-Adjective_offset Old) - (Baseline_offset-Adjective_offset Young)	0.224	1.021	0.219	1
(Baseline_offset-Adjective_offset Old) - (Between_Adjective-Noun Young)	-4.529	1.021	-4.437	0.0002
(Baseline_offset-Adjective_offset Old) - Noun Young	-7.767	1.021	-7.609	<.0001
(Between_Adjective-Noun Old) - Noun Old	-1.196	0.581	-2.059	0.4422
(Between_Adjective-Noun Old) - (Baseline(0-200) Young)	7.891	1.021	7.731	<.0001
(Between_Adjective-Noun Old) - (Baseline_offset-Adjective_offset Young)	4.337	1.021	4.249	0.0006
(Between_Adjective-Noun Old) - (Between_Adjective-Noun Young)	-0.416	1.021	-0.408	0.9999
(Between_Adjective-Noun Old) - Noun Young	-3.654	1.021	-3.58	0.0083
Noun Old - (Baseline(0-200) Young)	9.087	1.021	8.903	<.0001
Noun Old - (Baseline_offset-Adjective_offset Young)	5.533	1.021	5.42	<.0001
Noun Old - (Between_Adjective-Noun Young)	0.78	1.021	0.764	0.9948
Noun Old - Noun Young	-2.458	1.021	-2.408	0.2372
(Baseline(0-200) Young) - (Baseline_offset-Adjective_offset Young)	-3.555	0.528	-6.737	<.0001
(Baseline(0-200) Young) - (Between_Adjective-Noun Young)	-8.307	0.528	-15.744	<.0001
(Baseline(0-200) Young) - Noun Young	-11.545	0.528	-21.88	<.0001
(Baseline_offset-Adjective_offset Young) - (Between_Adjective-Noun Young)	-4.753	0.528	-9.007	<.0001
(Baseline_offset-Adjective_offset Young) - Noun Young	-7.99	0.528	-15.143	<.0001
(Between_Adjective-Noun Young) - Noun Young	-3.238	0.528	-6.136	<.0001

*Table (5) :Results of linear mixed effect model (model formula: fixation ~ time_window * group + (1 | Participants) + (1 | trial) for Experiment 2.*

Fixed effects	**Estimate**	**Std. Error**	***t***	***p***
Intercept	-0.7414	1.0384	-0.714	0.477189
Timewindow Baseline_offset-Adjectice_offset	2.5287	0.564	4.483	<0.0001
Timewindow Between_Adjective-Noun	6.2155	0.564	11.02	<0.0001
Timewindow Noun	7.4502	0.564	13.209	<0.0001
Group Young	-0.8786	1.1298	-0.778	0.439422
Timewindow Baseline_offset-Adjectice_offset : Group Young	0.6256	0.7982	0.784	0.433215
Timewindow Between_Adjective-Noun : Group Young	2.8215	0.7982	3.535	0.000412
Timewindow Noun : Group Young	3.4267	0.7982	4.293	<0.0001

Table (6): Contrast result for Experiment 2

contrast	**estimate**	**SE**	**z.ratio**	**p.value**
(Baseline(0-200) Old) - (Baseline_offset-Adjectice_offset Old)	-2.529	0.564	-4.483	0.0002
(Baseline(0-200) Old) - (Between_Adjective-Noun Old)	-6.215	0.564	-11.02	<.0001
(Baseline(0-200) Old) - Noun Old	-7.45	0.564	-13.209	<.0001

(Baseline(0-200) Old) - (Baseline(0-200) Young)	0.879	1.13	0.778	0.9943
(Baseline(0-200) Old) - (Baseline_offset-Adjectice_offset Young)	-2.276	1.13	-2.014	0.472
(Baseline(0-200) Old) - (Between_Adjective-Noun Young)	-8.158	1.13	-7.221	<.0001
(Baseline(0-200) Old) - Noun Young	-9.998	1.13	-8.85	<.0001
(Baseline_offset-Adjectice_offset Old) - (Between_Adjective-Noun Old)	-3.687	0.564	-6.536	<.0001
(Baseline_offset-Adjectice_offset Old) - Noun Old	-4.921	0.564	-8.726	<.0001
(Baseline_offset-Adjectice_offset Old) - (Baseline(0-200) Young)	3.407	1.13	3.016	0.0522
(Baseline_offset-Adjectice_offset Old) - (Baseline_offset-Adjectice_offset Young)	0.253	1.13	0.224	1
(Baseline_offset-Adjectice_offset Old) - (Between_Adjective-Noun Young)	-5.63	1.13	-4.983	<.0001
(Baseline_offset-Adjectice_offset Old) - Noun Young	-7.47	1.13	-6.612	<.0001
(Between_Adjective-Noun Old) - Noun Old	-1.235	0.564	-2.189	0.3582
(Between_Adjective-Noun Old) - (Baseline(0-200) Young)	7.094	1.13	6.279	<.0001
(Between_Adjective-Noun Old) - (Baseline_offset-Adjectice_offset Young)	3.94	1.13	3.487	0.0115
(Between_Adjective-Noun Old) - (Between_Adjective-Noun Young)	-1.943	1.13	-1.72	0.6743
(Between_Adjective-Noun Old) - Noun Young	-3.783	1.13	-3.348	0.0185
Noun Old - (Baseline(0-200) Young)	8.329	1.13	7.372	<.0001
Noun Old - (Baseline_offset-Adjectice_offset Young)	5.174	1.13	4.58	0.0001
Noun Old - (Between_Adjective-Noun Young)	-0.708	1.13	-0.627	0.9985
Noun Old - Noun Young	-2.548	1.13	-2.255	0.3187
(Baseline(0-200) Young) - (Baseline_offset-Adjectice_offset Young)	-3.154	0.565	-5.584	<.0001
(Baseline(0-200) Young) - (Between_Adjective-Noun Young)	-9.037	0.565	-15.998	<.0001
(Baseline(0-200) Young) - Noun Young	-10.877	0.565	-19.256	<.0001
(Baseline_offset-Adjectice_offset Young) - (Between_Adjective-Noun Young)	-5.883	0.565	-10.414	<.0001
(Baseline_offset-Adjectice_offset Young) - Noun Young	-7.723	0.565	-13.671	<.0001
(Between_Adjective-Noun Young) - Noun Young	-1.84	0.565	-3.257	0.0249