Learning with friends and strangers: does familiarity improve performance for younger and older adults on a collaborative referencing task?

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Abstract

Collaborative learning with a familiar partner can reduce age-related differences in learning and memory. This study compares younger and older adults' learning with familiar and unfamiliar partners to determine whether familiarity improves performance in a collaborative learning task. This study involved 24 younger adults aged 18-28 years and 24 older adults aged 60-80 years in familiar and unfamiliar pairs. Participants were asked to arrange abstract tangram shapes in a specific order on a grid over multiple trials. Each participant pair featured a director and a matcher; the directors' tangram cards were arranged in a specific order on the grid and this order was communicated to the matcher. Each trial featured a different order of tangram cards, requiring participants to create, learn and apply efficient referential labels for each card. Older adults initially took longer to complete the task, using more words to correctly arrange the tangrams. Over multiple trials, a learning effect was observed in both groups, although older adults did not perform with similar efficiency to younger adults. Familiarity had no effect on performance, suggesting that the familiarity of a partner might not affect learning outcomes in a task that does not specifically rely on transactive memory.

Keywords: aging; social interaction; learning; memory; collaborative learning

Introduction

Cognitive aging is associated with a deterioration in performance on memory tasks, and in the speed and accuracy of learning (Hedden & Gabrieli, 2004; Logie & Maylor, 2009). This decline is particularly apparent in declarative memory tasks in the relative absence of change in non-declarative memory (La Voie & Light, 1994; Rönnlund, Nyberg, Bäckman, & Nilsson, 2005). Both cross-sectional and longitudinal studies have found that the ability to encode and recall information differs significantly between younger and older adults particularly after the sixth decade (Park et al., 2002; Wilson et al., 2002; Zelinski & Burnight, 1997).

The literature on ageing has typically considered memory as an independent, solitary phenomenon, where participants learn and are assessed individually (Mahr & Csibra, 2018; Rönnlund et al., 2005; Strough & Margrett, 2002). However, this does not reflect many real-world learning opportunities, where new information and skills are often learned with other people within a social context. Yet, only a small body of research has examined memory in the wider context of social interactions with others (Staudinger & Baltes, 1996; Strough & Margrett 2002). Investigating how older adults interact and learn with their close social partners such as spouses and friends, as well as strangers, has important implications for our understanding of memory in everyday life. Exploring cognition in a social context, rather than on an individual, isolated basis, may lead to an improved understanding of cognition across the lifespan (Strough & Margrett, 2002). With an aging population, greater investigation and understanding of collaborative learning in older adults has become increasingly pertinent (Martin & Wight, 2008).

While older adults consistently show a decline in memory performance when assessed individually (Hultsch, Hertzog, Dixon, & Small, 1998; Zelinski & Burnight,

1997), learning with another person may ameliorate age-related differences in learning and memory (Derksen et al., 2014). Performance on other cognitive assessments can be improved by engagement in collaborative problem-solving activities compared with control groups of other adults working individually (Bassuk, Glass & Berkman, 1999; Duff et al., 2008; Parisi, Stine-Morrow, Noh & Morrow, 2009; Stine-Morrow & Parisi, 2008). Performance is better on general cognitive tasks incorporating a social and collaborative context, compared with tasks designed to be completed individually (Vygotsky, 1978). When completing problem solving tasks, working in collaboration with others can result in superior outcomes compared with working alone (Finlay, Hitch, & Meudell, 2000; Vygotsky, 1978).

Derksen et al. (2014) used the Barrier Task, a learning task where pairs of participants created and learned referential labels for tangrams shapes, and therefore were required to work collaboratively and interact socially with their partner to complete the task. The Barrier Task was originally designed to explore referential communication in children's language development (Krauss & Weinheimer, 1964; Kruass, Robert & Glucksberg, 1969) but later adapted to analyse learning in older adults, and adults with amnesia (Derksen et al., 2014; Duff, Hengst, Tranel & Cohen, 2008, 2006). Derksen et al. (2014) found that older adults performed similarly to younger adults after multiple learning trials, despite the older adults having poorer episodic memory than the younger adults when assessed individually (Derksen et al., 2014; Johansson, Andersson, & Rönnerberg, 2005; Martin & Wight, 2008; Ross, Spencer, Linardatos, Lam, & Perunovic, 2004).

Two accounts have been put forward to explain the advantages associated with collaborative learning: re-exposure during encoding (Blumen & Rajaram, 2008; Blumen et al., 2013; Weldon & Bellinger, 1997), and cross-cueing during retrieval

(Blumen & Rajaram, 2008; Blumen & Stern, 2011; Blumen et al., 2013; Congleton & Rajaram, 2011; Meudell, Hitch, & Boyle, 1995; Meudell, Hitch, & Kirby, 1992; Meudell, 1996). *Re-exposure* suggests that the collaborative learning partner provides re-exposure to the learning material that would not have occurred if learning alone. For example, while one person (person A) may not remember what they had eaten at a family meal the previous week, the other person (person B) may remember this. When these individuals recall collaboratively, person A is re-exposed to this information and is subsequently more likely to recall this information at a later point (Blumen, Rajaram, & Henkel, 2013). Therefore, collaboration gives a person the opportunity to re-learn information provided by their partner which they would not have recalled alone (Blumen et al., 2013). *Cross-cueing* involves a collaborator providing information that acts as a retrieval cue, prompting the other participant to recall information that they would not have remembered if recalling on their own (Blumen et al., 2013). For example, when trying to recall what was eaten at a family meal, one person may recall and mention that the family had used a new set of hand-painted dinner plates. This may then cue the other person's memory to recall what they had eaten, a trigger that would not have been available without the retrieval cue (Blumen et al., 2013). In summary, during collaboration, re-exposure provides additional opportunities to learn the information, and cross-cueing provides additional prompts and recall opportunities (Blumen et al., 2013). Often re-exposure and cross-cueing occur together; as re-exposure increases, the opportunities to cross-cue also increase, because more cues are created in order to aid retrieval (Blumen & Rajaram, 2008; Blumen & Stern, 2011; Blumen et al., 2013; Congleton & Rajaram, 2011; Weldon & Bellinger, 1997).

Another possible explanation for the benefits of collaborative learning is that memory is enhanced for information that is self-relevant and social compared with

neutral and non-social information (Cassidy & Gutchess, 2012; May, Rahhal, Berry, & Leighton, 2005; Yang et al., 2012). By learning collaboratively, and interacting with a partner throughout the learning process, the information learned becomes placed in the wider context of a social interaction, which is not the case for information learned individually. As the encoding of self-relevant or social information is prioritized, individuals benefit from learning in a social context.

This prioritization of encoding self-relevant information aligns with the scaffolding theory of aging and cognition, which states that scaffolding is a process that occurs during healthy aging where alternative, complementary neural systems develop to achieve a cognitive goal (Park & Reuter-Lorenz, 2009). Thus, while age-related changes in memory performance are common, in certain recall contexts, such as those scaffolded by social interaction with another person, older adults can ameliorate reductions in memory performance and perform at a higher level (Blumen et al., 2013; Park & Reuter-Lorenz, 2009).

Recent collaborative learning research has largely utilized paradigms involving participants learning with a familiar person (Duff et al., 2008; Derksen et al., 2014). For example, older, long-term married couples have been found to perform significantly better when collaboratively recalling episodic details about autobiographical memories than when recalling them alone (Barnier et al., 2014; Harris, Barnier, Sutton, Keil & Dixon, 2017). Most studies have not contrasted people learning with familiar people with learning with strangers, and so the role of familiarity in collaborative learning has been under-investigated. Early theories of collaboration such as the transactive memory theory (Wegner, 1987; Wegner, Giuliano, & Hertel, 1985) propose that partners who are collaborating depend on existing awareness of their partner's knowledge, which allows participants to focus on encoding information

that relates only to their individual knowledge. Partners who know each other very well can develop an implicit understanding of each other's knowledge, which allows them to jointly solve memory tasks, with the couple's transactive memory being superior to their individual memories. Collaborators provide additional learning opportunities, and additional cues for recall, as in the cross-cueing and re-exposure theories. Importantly, however, cross-cueing and re-exposure do not rely on participants being familiar with one another when learning and should apply when participants are learning with both friends and strangers.

In this study, we investigated whether familiarity enhances the effect of collaboration on older and younger adults' memory performance. The study uses an adapted version of the Barrier Task paradigm (Derksen et al., 2014). The social aspect of the task is emphasized by its game-like nature, and participants interact in the naturalistic setting of a social interaction and joint problem-solving. Participants are required to arrange a set of tangrams in a specific order on a grid over multiple trials; a task which involves them jointly creating referential labels for each of the tangram shapes, and then learning these referential labels and using them to efficiently complete the trials. By developing a mutual understanding of the shapes and their labels, participants are able to complete the task in an increasingly faster manner. We hypothesized that, as in Derksen et al. (2014), familiar pairs of older adults would become more efficient over Barrier Task trials. In addition, we hypothesized that familiarity might boost this effect. Shared episodic memories might make it easier for participants to cross-cue each other. On the other hand, if the main factor is re-exposure, then performance should not depend on participants knowing one another.

Method

Participants. Twelve younger adults aged 18-30 years and twelve older adults aged 60-80 years attended the Department of Psychology at the University of Edinburgh. Each participant was required to bring another volunteer who was either a friend, relative, or partner who they had known for at least two years, spoke to at least once a week, and was in the same age group. The pairs could be same or mixed gender. Thus, the final sample was 24 younger (16 female, aged 18-28 years) and 24 older (16 female, aged 60-80 years) community dwelling adults. All participants were native speakers of English and were screened for neurological or medical conditions using the Wechsler Memory Scale-III (WMS-III; Wechsler, 1997) exclusion criteria.

Materials and procedure. The Test of Premorbid Functioning (Wechsler, 2009) was administered to provide a measure of full scale IQ. The Rey Osterreith Complex Figure Test (Bernstein, & Waber, 1996) was administered to assess visuospatial memory, and the Digit Span subtest from the WAIS-IV (Wechsler, 2008) assessed working memory. Executive function was assessed using the Plus-Minus task (Hull, Martin, Beier, Lane, & Hamilton, 2008; Jersild, 1927); and the Self Ordered Pointing Task (MacPherson, Phillips, & Della Sala, 2002; Petrides & Milner, 1982) were administered.

The Barrier Task. The Barrier Task was administered according to Duff, Hengst, Tranel and Cohen (2008) and Derksen et al. (2014). The task involved two participants: one assigned the role of Director; and the other of Matcher. The Director and Matcher sat opposite one another at a table separated by a 9-inch barrier in the middle of the table. Each participant had a 6 x 2 grid in front of them with 12 numbered spaces and a set of 12 cards that all featured a black tangram shape (approx. 2 x 3 inches) on a white background (approx. 3.5 x 5.5 inches). The participants' view of the

other person's grid and cards was obscured but not their view of the other person's face or gestures.

The Director's tangram cards were arranged in a predetermined order on their grid. The Director was required to communicate this order to the Matcher by describing the card in each numbered space starting with the first tangram, and then subsequent tangrams in ascending order. The Matcher's role was to recreate the Director's card order on their own grid. Participant pairs were told that they could communicate with one another in any way they liked, but they could not show each other the tangram cards. They were told that they would not be timed, and to treat the task as a game and to have fun. Once the Matcher had recreated the Director's card order, the researcher rearranged the Director's cards in a second predetermined order, and the procedure was repeated. Each complete reordering of the 12 tangram cards was defined as one trial. Participants were asked to complete nine trials of the Barrier Task in a single session. All trials were video recorded, and transcribed using the methodology outlined by Duff, Hengst, Tranel and Cohen (2008). Half of the participants completed nine trials using one set of tangram cards with a familiar partner, before completing an additional nine trials using a different set of cards and an unfamiliar partner. The other half completed nine trials firstly with an unfamiliar partner and then nine trials with a familiar partner. The card set used was also counterbalanced across participants, and each of the participants played the role of Director either with a familiar or unfamiliar partner and Matcher either with a familiar or unfamiliar partner. Participants completed the Barrier Task in a single session and returned individually to complete the neuropsychological test session later that week. Participants were remunerated for their time.

The Barrier Task includes three dependent variables: time to complete the task, number of words used, and number of interactive turns taken (Derksen et al., 2014;

Duff et al., 2008). Time to complete is defined as the amount of time participants take to complete each trial, measured in seconds. The number of words is the total number of words including filled pauses such as “um” and “ah”. Contractions such as “don’t” count as one word. A turn was defined as a participant’s utterance, with the end of the turn defined by a change in speaker. If participants spoke simultaneously, each of the participants’ utterances were included as a turn.

Previous research using the Barrier Task has specifically focused on interactive measures when the participant was in the Director role (Derksen et al., 2014). As successful performance on the Barrier Task depends on the learning of both the Director and Matcher, the current study considers the Director and Matcher’s time and number of turns taken together in the same interaction(i.e. a single trial), but considers the number of words separately for both Directors and Matchers.

Results

Demographic and neuropsychological data. The younger and older groups’ demographic characteristics and performance on the background measures are demonstrated in Table 1. The two groups were compared on demographic and cognitive variables using independent samples t-tests if the data were normally distributed, or Mann-Whitney-Wilcoxon tests if the data were non-normally distributed. The older group were more highly educated than the younger adults, had a significantly higher IQ, and had known their familiar partner for a longer period of time. While older adults performed significantly more poorly on visuospatial memory than younger adults, the two age groups did not differ on story recall, digit span, semantic memory or executive abilities.

- Insert Table 1 here -

The Barrier Task. In line with previous Barrier Task studies (Derksen et al., 2015; Duff et al., 2008), the nine trials were collapsed into three trial bins to minimize inter-trial noise. To test the effects of age group, familiarity condition and trial number on the number of words used, number of turns taken, and time taken to complete, linear mixed models (LMMs) were used, since this allows distinguishing between participant-level and trial bin-level predictors, and can be applied to non-normal data. LMMs were implemented using the ‘lme’ function of the lme4 package, version 1.1-8 (Bates, Maechler, Bolker & Walker, 2013) in R 3.2.2 (R Core Team, 2015). The threshold for statistical significance was $|\text{t}| < 2$.

A forward stepwise approach was used to select factors for the final model using likelihood ratio tests to compare models. The random effects structure was reduced to trial bin by participant to avoid model over-specification. All best fitting models included the main effects and interaction between age group (younger or older) and trial (1, 2, or 3), and a main effect of familiarity condition (familiar or unfamiliar). Including familiarity as an interaction did not significantly improve model fit, and so this interaction was not included in the final models (Table 2). For time taken to complete and number of turns taken, the models included random slopes and intercepts for trial bin and familiarity condition by participant. Familiarity was removed as a random effect as it did not significantly influence model fit in other models.

In general, all three dependent variables on the Barrier Task showed a similar pattern; participants took more time, turns, and words to complete the initial, early trials, but by the later trials, participants took less time, turns and words to complete.

Initially, the older adults were less efficient than the younger participants in terms of time, turns and words, but this age difference reduced across trials.

Figure 1 illustrates performance for time to complete, number of words used, and number of turns taken for each age group across each condition. Each of the analyses revealed a main effect of age group, trial bin, and an age group x trial bin interaction (see Tables 3 and 4). For number of words used by both Directors and Matchers, the interaction between age group and trial bin was only significant across trial bins 1 to 2 (Bin 1-2 Director words $B = -74.15$, $SE = 22.89$, $t = -3.24$; Matcher words $B = -36.32$, $SE = 10.52$, $t = -3.45$) and not in bins 2 to 3 (Bin 2-3 Director words $B = -36.60$, $SE = 22.88$, $t = 1.60$; Matcher words $B = -19.08$, $SE = 10.45$, $t = -1.82$) indicating that the older and younger adults were using a similar number of words in mid and later trials (see Table 5).

- Insert Figure 1, Table 2, Table 3 and Table 4 here -

Learning performance in bin 3. Younger and older adults' performance in trial bin 3 was compared to explore whether learning using this collaborative paradigm resulted in younger and older adults performing with similar efficiency. As familiarity had no effect on performance, familiarity was not included in these contrasts. The analyses indicated that younger adults were still significantly faster than older adults by the final trials, using significantly fewer turns and words (see Table 5), though the difference between the older and younger groups in later trials was significantly less than the difference in early trials.

- Insert Table 5 here -

Power Analysis

Effect size was calculated using the ‘cohensD’ command from the ‘lsr’ R package (Navarro, 2015), and power analysis was calculated using the ‘pwr.2p.test’ from the ‘pwr’ R package (Champely, 2016). Table 6 shows the means for older and younger adults on each of the dependent variables, along with the effect sizes and power.

- Insert Table 6 -

Relationship with neuropsychological test performance. Spearman’s correlational analyses with a False Discovery Rate (FDR; Benjamini & Hochberg, 1995) correction for multiple comparisons explored relationships between the three Barrier Task variables (time to complete, number of words, number of turns), age, and cognitive test performance in younger and older participants (see Tables 7a and 7b). In the older group, there were only two significant associations. Visuospatial memory was related to the number of turns taken ($r = 0.38, p = 0.02$), and semantic memory was associated with time to complete ($r = 0.48, p = 0.009$). In the younger adult group, number of turns was associated with executive function as measured by the plus-minus task ($r = -0.46, p = 0.02$); no other relationships were found.

- Insert Tables 7a and 7b here -

Discussion

The current study investigated whether familiarity significantly improves learning in a social context, and whether younger and older adults can learn collaboratively with similar efficiency.

Older and younger adults both showed similar improvements in learning efficiency with a close friend or partner as they did with a stranger, suggesting that familiarity does not affect learning outcomes, and that collaboration alone may be sufficient to result in successful learning. These results indicate that learning can be similarly accurate with friends and strangers, and that speed of learning is not affected by familiarity during collaboration. This aligns with re-exposure during encoding (Blumen & Rajaram, 2008; Blumen et al., 2013; Weldon & Bellinger, 1997), and cross-cueing during retrieval theories of collaboration (Blumen & Rajaram, 2008; Blumen & Stern, 2011; Blumen et al., 2013; Congleton & Rajaram, 2011; Meudell, Hitch, & Boyle, 1995; Meudell, Hitch, & Kirby, 1992; Meudell, 1996). Collaboration may allow learners to access information provided by their partner which they would not have recalled alone, re-exposing them to relevant information and giving them the opportunity to re-learn this information (Blumen et al., 2013). Collaborators may also cross-cue; providing information which acts as a retrieval cue and prompting the learner to recall information that they would not have remembered on their own (Blumen et al., 2013). Importantly, this does not depend on collaborators knowing each other, as in the unfamiliar condition of this study. This suggests that in this particular task, effective cross-cueing does not depend on

However, the Barrier Task is not thought to incorporate or rely upon participants' prior knowledge, nor is the task set within a wider social context. Many real-world collaborations involve aspects of previous shared experience and knowledge. It may be that more complex tasks, incorporating previously learned skills or knowledge, may show different patterns of performance with familiar and unfamiliar pairs. Future work may involve more complex tasks that incorporate previously learned skills to investigate whether collaboration alone is sufficient to improve learning

performance regardless of whether the pairs are familiar to one another or not.

The secondary aim of this study was to investigate whether the finding that older adults could perform similarly to younger adults on a collaborative learning task (Derksen et al., 2014) could be replicated. Older adults performed less efficiently than younger adults at the start of the Barrier Task, using more words and taking more time and turns to complete the task. By the end of the trials, the older group were still significantly less efficient in terms of words, turns, and time than younger group at completing the task, although the difference between the two groups was considerably less, and the difference between the two groups reduced over trials. However, unlike previous research (e.g., Derksen et al., 2014), our older adults were still not performing as well as our younger adults by the end of the nine trials. It is possible that with a higher number of trials, our two age groups may have become statistically indistinguishable.

One limitation of using the Barrier Task is that it does not allow for assessment of individual memory performance. Therefore, a direct comparison between individual and collaborative performance was not possible; without a director to tell you how to sort the tangrams, there may not be a simplification in referential labels across trials (Hupet & Chantraine 1992, Derksen et al., 2014). Individual memory performance was therefore assessed using the Rey Osterreith Complex Figure test as a standardized measure of memory (Bernstein & Waber, 1996); with results indicating that individual memory ability was not clearly related to Barrier Task efficiency. Older adults' individual visuospatial memory performance was correlated with turns taken during the Barrier Task; and no relationship was found between the two tasks in the younger group. This echoes Derksen et al.'s (2014) findings that performance on the Barrier Task and individual anterograde visual memory tasks (using the Visual Representation

Task from the Wechsler Memory Scale – III (Wechsler, 1997) are correlated in older, but not younger adults.

These results indicate that collaborative memory ability may be at least in part independent of individual memory ability, as indicated by studies of amnesic patients who showed robust learning through collaboration, at a rate equal to non-amnesic comparative controls, despite marked inability to learn arbitrary relations in paired associate learning (Duff et al., 2006; Duff et al. 2008). As collaborative learning involves a social interaction with another person, it may instead be supported by and related to socio-cognitive skills. Memory is enhanced for information that is self-relevant and social compared with neutral and non-social information (Cassidy & Gutchess, 2012; May, Rahhal, Berry, & Leighton, 2005; Yang et al., 2012) this may explain why collaborative learning is beneficial; it places the newly learned information in the wider context of a social interaction. As the encoding of self-relevant or social information is prioritized, individuals may benefit from learning in a social context.

The study did have some limitations; firstly, the relationship length was uneven across the two groups, with older adults having a significantly longer relationship with their familiar partner than the younger pairs, though arguably this was beneficial for the older adults. Secondly, the sample size was small, though post-hoc power calculations showed large effect sizes and high statistical power for early trials and smaller effect sizes and lower statistical power for the later trials. This is expected due to the nature of the task; as participants complete each trial, they learn the labels for each tangram and are able to recall the labels more quickly, and the difference between the two groups becomes less. A larger sample may confirm that the lack of differences

between the two groups in the final trials is a true effect and not due to lower statistical power.

Future work may focus on understanding the socio-cognitive mechanisms that underpin collaborative learning in more depth, as well as investigating individual differences in collaborative learning to explore whether it might be particularly useful for certain groups of older adults. For example, it may be useful to explore whether collaborative learning is particularly useful for older adults who are very socially competent and socially engaged. This may in turn shed light on whether this type of learning is beneficial to patient groups who have memory impairment but intact social cognitive function. Indeed, Duff et al. (2006) found that patients with hippocampal amnesia successfully learned the order of the tangrams when performing the Barrier Task in collaborative pairs. Similarly, the Barrier Task has been used to show successful collaborative learning in Alzheimer's patients, who typically show memory impairment (Duff, Gallegos, Cohen, & Tranel, 2013). However, Duff and colleagues did not assess the social-cognitive profiles of their patients in either study. In addition, the future investigation of familiarity effects in collaborative learning with patient groups may have potentially important clinical applications. For example, if amnesic patients learn better with a familiar caregiver than with an unfamiliar nurse, it may be advisable to train the familiar person to communicate new skills or information to the amnesic individual instead of a nurse.

Our findings that there are no differences in collaborative learning when performing the Barrier Task with familiar and unfamiliar partners have both useful and practical implications. Older adults learn new information from a number of people that they may not know: doctors, people in the community, and through lifelong education projects. Our study suggests that older adults should not feel deterred from

learning new things in a collaborative setting, even if they do not know the people involved; it may be that they can learn as well with a stranger as they would with a close friend. This research may also have implications for lifelong learning and adult education, as it may be beneficial to learn in a context that emphasizes interactive, collaborative learning rather than individual learning.

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Table 1: Demographic and cognitive characteristics and comparisons of younger and older groups

				Younger (n= 24)	Older (n= 24)	p
Age (years)	M			21.25	66.88	< 0.0001
	SD			2.69	7.19	
Gender	M/F			8/16	8/16	
Handedness	L/R			1/23	1/23	
Relationship length (years)	M			4.67	37.08	< 0.0001
	SD			6.14	17.59	
Education (years)	M			15.17	16.02	< 0.0001
	SD			1.49	2.29	
ToPF Full Scale IQ (<i>max = 127</i>)	M			105.61	115.12	< 0.0001
	SD			6.13	6.67	
ROCF Immediate Recall (<i>max = 36</i>)	M			26.46	20.10	< 0.001
	SD			4.10	6.61	
ROCF Delayed Recall (<i>max = 36</i>)	M			25.83	18.19	< 0.0001
	SD			3.82	6.07	
WAIS-IV Digit Span Forwards Score (<i>max = 16</i>)	M			11.50	11.63	= 0.87
	SD			2.40	2.16	
WAIS-IV Digit Span Backwards Score (<i>max = 16</i>)	M			9.17	10.09	= 0.27
	SD			2.79	2.84	
	SD			2.71	4.48	
Plus Minus Task (<i>max = 100</i>)	M			72.18	66.56	= 0.11
	SD			8.31	14.71	
Self-Ordered Pointing Task (<i>max = 36</i>)	M			31.42	29.29	< 0.05
	SD			2.98	3.92	

ToPF: Test of Premorbid Functioning; ROCF: Rey Osterreith Complex Figure Test;
WAIS-IV: Wechsler Adult Intelligence Scale-IV.

Table 2: Model comparisons for Time, Turns, Director Words and Matcher words if Linear Mixed Effects Models by REML, with best fitting model shown in bold.

Time to complete										
M	Fixed Effects	Random Effects	Df	AIC	BIC	logLik	Deviance	ChiSq	Chi DF	p (ChiSq)
1	None (1)	1 + (Familiarity + Bin) Participant	12	3025.6	3069.6	-1500.8	3001.6			
2	Age	1 + (Familiarity + Bin) Participant	13	3025.2	3072.9	-1499.6	2999.2	2.38	1	0.12
3	Age + Familiarity	1 + (Familiarity + Bin) Participant	14	3026.3	9077.5	-1499.1	2999.3	0.98	1	0.32
4	Age * Familiarity	1 + (Familiarity + Bin) Participant	15	3026.6	3081.5	-1498.3	2996.6	1.67	1	0.20
5	Age + Familiarity + Bin	1 + (Familiarity + Bin) Participant	16	2947.8	3006.4	-1457.9	2915.8	82.43	2	< 2.2e-16 ***
6	Age * Bin + Familiarity	1 + (Familiarity + Bin) Participant	18	2908.7	2974.6	-1436.3	2872.7	43.13	2	4.31e-10 ***
7	Age * Bin * Familiarity	1 + (Familiarity + Bin) Participant	23	2914.6	2998.9	-1434.3	2868.6	4.08	5	0.54
Turns Taken										
1	None (1)	1 + (Familiarity + Bin) Participant	12	1611.0	1655.0	-793.52	1587.0			
2	Age	1 + (Familiarity + Bin) Participant	13	1608.9	1656.5	-791.45	1582.9	4.13	1	0.04*
3	Age + Familiarity	1 + (Familiarity + Bin) Participant	14	1610.6	1661.8	-791.28	1582.6	0.34	1	0.56
4	Age * Familiarity	1 + (Familiarity + Bin) Participant	15	1612.0	1667.0	-791.01	1582.0	0.55	1	0.46
5	Age + Familiarity + Bin	1 + (Familiarity + Bin) Participant	16	1521.1	1579.7	-744.55	1489.1	93.48	2	< 2.2e-16 ***
6	Age * Bin + Familiarity	1 + (Familiarity + Bin) Participant	18	1503.2	1569.1	-733.58	1467.2	21.93	2	1.731e-05 ***
7	Age * Bin * Familiarity	1 + (Familiarity + Bin) Participant	23	1510.2	1594.4	-732.07	1464.2	3.01	5	0.70
Director Words										
1	None (1)	1 + (Bin) Participant	5	1819.4	1834.3	-904.71	1809.4			
2	Age	1 + (Bin) Participant	6	1805.3	1823.1	-896.64	1793.3	16.13	1	5.92e-05 ***
3	Age + Familiarity	1 + (Bin) Participant	7	1804.6	1825.4	-895.30	1790.6	2.69	1	0.10
4	Age* Familiarity	1 + (Bin) Participant	8	1806.1	1829.5	-895.04	1790.1	0.52	1	0.47
5	Age + Familiarity + Bin	1 + (Bin) Participant	9	1658.4	1685.1	-820.18	1640.4	150.23	2	< 2.2e-16 ***

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6	Age * Bin + Familiarity	1 + (Bin) Participant	11	1639.9	1672.5	-808.93	1617.9	22.50	2	1.299e-05 ***
7	Age * Bin * Familiarity	1 + (Bin) Participant	16	1638.5	1665.2	-810.24	1620.5	2.60	5	0.2718
Matcher Words										
1	None (1)	1 + (Bin) Participant	5	1549.7	1564.5	-769.86	1539.7			
2	Age	1 + (Bin) Participant	6	1539.0	1556.8	-763.50	1527.0	12.72	1	0.0003* **
3	Age + Familiarity	1 + (Bin) Participant	7	1541.0	1561.7	-763.50	1527.0	0.006	1	0.93
4	Age* Familiarity	1 + (Bin) Participant	8	1542.9	1556.6	-763.44	1526.9	0.12	1	0.73
5	Age + Familiarity + Bin	1 + (Bin) Participant	9	1415.8	1442.5	-698.92	1397.8	129.25	2	<2.2e-16 ***
6	Age * Bin + Familiarity	1 + (Bin) Participant	11	1394.2	1426.8	-686.11	1372.2	25.64	2	2.713e-06 ***
7	Age * Bin * Familiarity	1 + (Bin) Participant	16	1403.8	1421.2	-685.92	1371.8	0.37	5	0.99

Table 3: Beta, standard errors, and t values for fixed effects on words, turns, and time

<u>Fixed effects</u>	<u>B</u>	<u>S.E.</u>	<u>T</u>
<u>Time to complete</u>			
Intercept	170.30	6.97	24.42**
Age group (older)	109.52	13.19	8.35**
Bin 1-2	-98.49	5.02	-19.64**
Bin 2-3	-17.56	3.98	-4.41**
Familiarity (unfamiliar)	9.41	7.02	1.33
Age (older) * bin 1-2	-62.05	9.72	-6.39**
Age (older) * bin 2-3	-27.37	7.92	-3.46**
<u>Number of turns taken</u>			
Intercept	23.39	0.59	39.88**
Age group (older)	6.62	1.16	5.67**
Bin 1-2	-9.59	0.50	-19.09**
Bin 2-3	-1.32	0.38	-3.47**
Familiarity (unfamiliar)	0.16	0.48	0.34
Age (older) * bin 1-2	-4.15	0.99	-4.17**
Age (older) * bin 2-3	-1.89	0.76	-2.48*
<u>Director words</u>			
Intercept	291.87	10.90	26.78**
Age group (older)	144.34	21.08	6.86**
Bin 1-2	-183.02	11.45	-15.99**
Bin 2-3	-28.77	11.45	-2.51*
Familiarity (unfamiliar)	23.30	17.33	1.52
Age (older) * bin 1-2	-74.15	22.89	-3.24**
Age (older) * bin 2-3	-36.60	22.88	-1.60
<u>Matcher words</u>			
Intercept	106.89	4.63	23.08**
Age group (older)	62.71	9.26	6.77**
Bin 1-2	-76.88	5.23	-14.47**
Bin 2-3	-10.88	5.22	-2.08*
Familiarity (unfamiliar)	-0.67	6.93	-0.09
Age (older) * bin 1-2	-36.32	10.52	-3.45**
Age (older) * bin 2-3	-19.08	10.45	-1.82

Table 4: Variance and residual for random effects, model fit by REML

<u>Random effects</u>		<u>Variance</u>	<u>Standard deviation</u>
<u>Time to complete</u> ^a			
Participant	Intercept	1660.18	40.75
	Familiarity (U)	1897.61	43.56
	Bin 1-2	506.50	22.51
	Bin 2-3	59.75	7.73
Residual		701.15	26.48
<u>Turns taken</u> ^a			
Participant	Intercept	13.41	3.66
	Familiarity (U)	6.75	2.59
	Bin 1-2	5.93	2.44
	Bin 2-3	0.77	8.76
Residuals		6.19	2.49
<u>Director words</u> ^b			
Participant	Intercept	2176	46.65
	Familiarity (U)	1519	38.98
Residuals		3144	56.07
<u>Matcher words</u> ^b			
Participant	Intercept	248.0	15.75
	Familiarity(U)	432.0	20.78
Residuals		655.5	25.60

^aNumber of observations = 96; ^bNumber of observations = 48

Table 5: Mann-Whitney-Wilcoxon U comparisons with FDR corrections for bin 3 variables of performance comparing younger and older adult groups.

Variable	Comparison
Time	$W = 1754, p = 0.00004152$
Turns	$W = 1540.5, p = 0.008$
Director words	$W = 412, p = 0.02$
Matcher words	$W = 394, p = 0.03$

Table 6: Mean group performance and mean group difference on the Barrier Task, with Effect Size calculated as Cohen's D, and statistical power calculated with a group size of 24, and a significant level of $p < 0.05$

	Bin 1	Bin 2	Bin 3
<u><i>Time to Complete</i></u>			
Younger	114.26	47.47	43.82
Older	226.33	96.15	64.68
Difference	112.07	48.68	20.86
Effect Size	1.67	1.41	0.91
Power	0.99	0.99	0.88
<u><i>Turns Taken</i></u>			
Younger	20.10	12.56	12.18
Older	26.68	15.03	12.76
Difference	6.58	2.48	0.58
Effect Size	1.18	1.07	0.41
Power	0.98	0.96	0.29
<u><i>Director Words</i></u>			
Younger	217.37	71.43	60.96
Older	156.58	44.04	23.56
Difference	80.80	26.36	7.28
Effect Size	1.33	1.33	0.84
Power	0.99	0.99	0.83
<u><i>Matcher Words</i></u>			
Younger	75.78	17.68	16.28
Older	156.58	44.04	23.56
Matcher	80.80	26.36	7.28
Effect Size	0.98	1.17	0.51
Power	0.92	0.98	0.43

Table 7a: Spearman's correlations between younger adults Barrier Task performance and performance on individual cognitive assessments

	1	2	3	4	5	6	7	8	9	10
Time (1)	1									
Words (2)	0.41**	1								
Turns (3)	0.83***	0.45**	1							
ToPF Full Scale IQ (4)	-0.14	-0.11	0.03	1						
ROCF Immediate Recall (5)	0.06	0.10	0.10	-0.16	1					
ROCF Delayed Recall (6)	0.01	0.05	0.10	-0.04	0.91***	1				
WAIS-IV Digit Span Forwards Score (7)	0.16	0.1	0.19	0.27	-0.08	0.02	1			
WAIS-IV Digit Span Backwards Score (8)	-0.14	-0.14	-0.08	0.49**	-0.03	0.21	0.46	1		
Plus Minus Task (9)	-0.30*	-0.21	-0.33*	-0.24	0.18	0.17	-0.43**	0.09	1	
Self-Ordered Pointing Task (10)	0.04	0.06	0.07	-0.18	-0.08	-0.18	-0.11	-0.34*	-0.30*	1
ToPF: Test of Premorbid Functioning; ROCF: Rey Osterreith Complex Figure Test; WAIS-IV: Wechsler Adult Intelligence Scale-IV. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$										

Table 7b: Spearman's correlations between older adults Barrier Task performance and performance on individual cognitive assessments

	1	2	3	4	5	6	7	8	9	10
Time (1)	1									
Words (2)	0.51**	1								
Turns (3)	0.72**	0.55**	1							
ToPF Full Scale IQ (4)	-0.17	-0.04	-0.18	1						
ROCF Immediate Recall (5)	-0.21	-0.15	-0.27	0.22	1					
ROCF Delayed Recall (6)	-0.21	-0.16	-0.3	0.19	0.91	1				
WAIS-IV Digit Span Forwards Score (7)	0.1	0.06	0.08	0.29	-0.23	-0.28	1			
WAIS-IV Digit Span Backwards Score (8)	-0.05	0.04	-0.14	0.36*	0.15	0.14	0.41**	1		
Plus Minus Task (9)	0	0.04	0.01	0.29*	0.25	0.24	0.25	0.32	1	
Self-Ordered Pointing Task (10)	0.02	-0.11	-0.14	-0.22	-0.17	-0.17	-0.40**	-0.38**	-0.58***	1
ToPF: Test of Premorbid Functioning; ROCF: Rey Osterreith Complex Figure Test; WAIS-IV: Wechsler Adult Intelligence Scale-IV. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Figures 1a (left) and 1b (right) mean and standard error of the mean for time to complete the barrier task (1a) and number of turns taken to complete the barrier task (1b) by trial bin, age group, and familiarity condition.

Figures 1c (left) and 1d (right) mean and standard error of the mean number of words used by directors (1c) and matchers (1d) by trial bin, age group, and familiarity condition.