Brief mindful breathing exercises and word retrieval performance in young and older adults

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Abstract. We tested whether performing a brief mindful breathing exercise could improve word and name retrieval performance for young and older adult participants by increasing correct responding and decreasing tip-of-the-tongue (TOT) states. Young (ages 18–35) and older (ages 60–80) adults were randomly assigned to engage in a short mindful breathing exercise or a control condition in which they listened to a relaxing story. They next performed a difficult definition-naming task (Experiment 1) or a naming task with faces of public figures (Experiment 2). Self-rated state mindfulness was higher for young but not older adults following mindful breathing than the control condition. Correct word retrieval scores correspondingly increased for young but not older adults following the intervention (Experiment 1), but no benefit was obtained when face naming was the dependent variable (Experiment 2). Neither young nor older adult participants' TOT rate decreased following mindful breathing in either experiment. Overall, we can conclude that brief mindful breathing exercises can benefit non-name word retrieval processes in young but not older adults. The improvement in correct naming without the corresponding reduction in TOTs indicates facilitation in lexical access rather than phonological access. Possible reasons for the obtained pattern of results are considered.

Keywords. speech production, naming, tip-of-the-tongue, mindful breathing, cognitive aging

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1 Brief mindful breathing exercises and word retrieval performance in young and older adults

Word retrieval is the process of producing a specific word 'on demand,' and it usually proceeds quickly and without errors. But sometimes people experience a temporary inability to retrieve and produce a specific term that they are certain they know and that they have used successfully in the past. This is called a "tip-of-the-tongue" (TOT) state. People experiencing TOTs report the subjective feeling that production is imminent. As an example, the question *What do you call a word or phrase that is spelled the same backward or forward?* should be answered with the word *palindrome,* but a speaker experiencing a TOT might say *I know that word! An example is 'Madam I'm Adam'. It starts with p … Not an anagram, but another word game …. Why can't I come up with it?!?* As this example shows, the speaker's knowledge about the word and their frustration with the experience are both clear during TOT states.

TOTs can be explained by the Transmission Deficit hypothesis (TDH; Burke et al. 1991), which posits that access to the phonological components (sounds) of words are particularly vulnerable to disuse and aging. A TOT occurs when a word's semantic information is accessed but some phonological information is temporarily inaccessible. In the *palindrome* example above, the speaker has retrieved the first sound of the word but they cannot retrieve the other sounds necessary for successful production.

Within the TDH model (Burke et al. 1991), word retrieval involves two systems of nodes: semantic and phonological. Semantic nodes represent word meaning, whereas phonological nodes represent the sounds that comprise words. Retrieval occurs through the processes of priming and activation within these systems. Priming refers to the spread of excitation through the network, enabling nodes to reach the activation threshold. Once a node receives sufficient priming, it can become activated, with its contents available for production. Connections among the semantic and phonological components of a word's representation all weaken when they have not been used recently or frequently. These weak connections are less able to effectively transmit priming. The structure of the model within which transmission deficits are instantiated posits that phonological components only have single connections via which they can accumulate priming for activation (unlike semantic nodes, which typically have multiple converging connections; e. g., Burke et al. 1991). This explains why TOTs occur: A failure of a single connection to transmit adequate priming for activation of the necessary phonology renders retrieval impossible. TOTs occur more often for rare than common words, because if a single connection has not been used recently, it may be unable to transmit adequate priming for phonological access even though semantic and lexical access has been achieved.

TOTs occur for adults of all ages, but are often found to increase with healthy aging (e. g., Burke et al. 1991; Heine, Ober, and Shenaut 1999; James 2006). The TDH holds that, as with disuse, connections weaken as people age, reducing priming transmission throughout the system and leading to older adults' specific increased difficulty retrieving the phonological components of words (Burke et al. 1991; MacKay and Burke 1990). Additional evidence supporting the TDH comes from studies showing that presenting the entire target word (Rastle and Burke 1996) or words that share sounds with the target word (James and Burke 2000; White and Abrams 2002) prior to word retrieval can bolster priming transmission, which reduces TOT incidence and also increases resolution of TOT states (i. e., when the word 'pops' into mind and is suddenly available for production).

James et al. (2018) tested whether young adult participants would experience more TOT states when they were tested in lab conditions designed to elicit stress. Using a modified version of the Trier Social Stress Test (Kudielka, Hellhammer, and Kirschbaum 2007), they told half of their participants they were being observed and evaluated while they gave a job interview-style speech followed by a mental subtraction task with answers spoken aloud, and finally a definition-naming test. Word retrieval data from these participants were compared to data from participants in a control condition who gave a speech about their favorite vacation spot and completed the math problems on a sheet of paper with no mention of evaluative observation before completing the same definition-naming test. Participants in the condition intended to elicit stress experienced more TOTs than participants in the control condition. Schmank and James (2020, Experiment 1) replicated that result with a group of older adult participants and using proper name as well as common noun stimuli. Their Experiment 2 was nearly identical to the first but had some procedural changes to make the testing conditions even more stressful, and included young, middle-aged, and older adult participants. The results again showed more TOTs for participants in the stressful than control condition, with an increase in TOT rate that was similar in magnitude for adults of all ages. The data in James et al. (2018) and Schmank and James (2020) provide evidence that TOTs can increase in laboratory testing conditions designed to elicit stress. However, there were no differences in self-reported state anxiety between participants in the stressful and non-stressful conditions in any of those three experiments. Nevertheless, the TSST procedure is known for its stress-inducing properties (Kudielka, Hellhammer, and Kirschbaum 2007), so the findings of James et al. (2018) and Schmank and James (2020) suggest that stress or anxiety can lead to increased TOT incidence. Within the TDH model, James et al. (2018) proposed that stress or anxiety might be a factor that temporarily reduces connection strength. As with other reductions in priming transmission within the network (MacKay and Burke 1990), the structure of the model predicts that phonological retrieval is particularly vulnerable to priming failures due to the one-to-one nature of connections to phonological components (e. g., Burke et al. 1991; James and Burke 2000). This hypothesized role for stress or anxiety was supported by the findings of James et al. (2018) and Schmank and James (2020).

Several findings in the literature indicated that short-term mindful breathing exercises can decrease anxiety and improve performance on cognitive tasks (e. g., Arch and Craske 2006; Eisenbeck, Luciano, and Valdivia-Salas 2018). As specific examples, Bonamo, Legerski, and Thomas (2015) found that associative recall was better after a 20-minute breathing exercise than after a 45-minute breathing exercise or a control condition, and Lueke and Lueke (2019) showed that verbal learning and memory were improved following a 10-minute breathing exercise compared to listening to a narrated description of the countryside. Silver, James, and Small (2021, Study 1) used these beneficial effects of mindful breathing to motivate a different approach to testing the relationship between stress and word retrieval. They implemented a manipulation in which young adult participants either did a mindful breathing exercise or were in a control condition prior to completing a picture naming task. Silver, James, and Small (2021) predicted that the mindful breathing exercise would lead to better picture naming task performance, and this prediction was supported. Silver, James, and Small

(2021) did not measure their participants' anxiety levels, but the anxiety-reducing effects of mindful breathing might be the factor underpinning the finding of improved word retrieval.

We could identify no previous research with older adult participants that incorporated mindful breathing exercises. Many publications explore whether older adults can benefit from longer-term interventions related to mindfulness (e. g., Lenze et al. 2014; Mallya and Fiocco 2016), but our experiments appear to be novel in testing for an immediate benefit of a short-term intervention with older adults. Although word retrieval might seem a surprising starting point for testing a brief mindful-breathing intervention, we reasoned that because adult aging is often accompanied by an increase in TOT states (e. g., Burke et al. 1991; Heine, Ober, and Shenaut 1999), and stressful testing conditions increased TOTs to a similar extent for adults of all ages (Schmank and James 2020), brief mindful breathing exercises might be effective in decreasing TOTs regardless of age. Furthermore, older adults anecdotally report that word retrieval failures can be anxiety-provoking or even distressing. Therefore, an exercise aimed at decreasing anxiety seemed promising as an intervention to improve word retrieval performance.

2 Experiment 1

The basic information about this experiment was preregistered on clinicaltrials.gov (NCT05066750), consistent with the reporting requirements for the funding mechanism at that time. We tested whether TOTs could be reduced, and correct naming increased, following a mindful breathing exercise. It was conducted during the height of the COVID 19 pandemic, so data collection occurred via videoconference calls and electronically-administered surveys. Because TOTs are somewhat rare in most laboratory studies (occurring on perhaps 5–10 % of trials), we aimed to generate robust TOT rates to allow detection of a reduction following mindful breathing. Restricting hand gestures has been suggested to decrease word retrieval performance (e. g., Frick-Horbury and Guttentag 1998), so our participants were made to hold their hands still in both conditions of the experiment, and we required participants to show themselves on video throughout testing to potentially increase their concerns about evaluative observation (e. g., Schmank and James 2020). These procedural elements were intended to elevate participants' potential evaluation anxiety in both conditions, which could increase their TOT rates (e. g., Schmank and James 2020), reducing the possibility of floor effects and allowing a clear test for a reduction in TOTs following the mindful breathing exercise.

We predicted a lower TOT rate and higher correct response rate following a mindful breathing exercise than in a control condition. This prediction followed from the extension to the TDH proposed by James et al. (2018): Inasmuch as stressful conditions temporarily reduce the transmission of priming and increase TOTs, mindful breathing could alleviate stress and anxiety and thereby facilitate priming transmission (a finding consistent with Silver, James, and Small 2021's picture naming results). Given the novelty of the manipulation with older adult participants, different magnitudes of benefit for the two age groups seemed possible, so we tested for an interaction of experimental condition and age group. We predicted a similar degree of facilitation for our young and older adult participant groups based on findings of similar benefits of phonological priming for both age groups (e. g., James and Burke 2000) and also

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based on Schmank and James (2020)'s finding that adults of all ages have increased TOT states in stressful testing conditions. However, the lack of prior research testing for effects of mindful breathing exercises in older adults meant we did not have an empirical basis for that prediction.

2.1 Method

Participants. We could find no published research testing brief mindful breathing exercises in older adults, so we followed Cohen (1992)'s "conventions...found to be reasonable by reasonable people" in our power analysis and designated a medium-sized effect as the minimum that would be considered useful (Anderson, Kelley, and Maxwell 2018). Age group and experimental condition were independent-groups variables, so sample size was determined for four groups of participants. Following Cohen (1992, Table 2), to achieve power of .80 with alpha set to .05 for medium-sized effects, we aimed to test 180 adults in total.

Young adult participants were students recruited from our university's Sona system and compensated with extra credit for Psychology classes. Data were collected from 86 people ages 18–30, but one person had connection problems during the word retrieval task and one person was unable to hear the audio for the manipulation, resulting in usable data from 84 young adults. Fifty-six identified as female, 27 as male, and 1 as other gender. Sixty-three people identified as white, 11 as more than one race, 6 as Black or African American, 3 as Asian, and 1 did not indicate their race. Eighteen people indicated their ethnicity as Hispanic or Latinx. Their mean age was 20.93 ($SD = 3.10$) and they had completed an average of 13.93 years of education ($SD = 2.13$). Their mean score on the Shipley (1940) vocabulary test was 28.86 correct (out of 40 possible; $SD = 3.46$; one young adult did not complete the vocabulary measure).

Older adult participants were recruited from a list of research volunteers maintained by our university's Gerontology Center and compensated with a $12 electronic gift certificate. Data were collected from 86 people ages 65–79, but two were unable to hear the audio for the manipulation, yielding 84 usable older adult participants. Sixty participants identified as female and 24 as male. Seventy-nine people identified as white, 3 as more than one race, 1 as Black or African American, and 1 did not indicate their race. Five people indicated their ethnicity as Hispanic or Latinx. Their mean age was 71.85 ($SD = 3.85$) and they had completed an average of 17.08 years of education ($SD = 2.48$). Their mean score on the Shipley (1940) vocabulary test was 36.70 correct ($SD = 2.24$; four older adults did not complete the vocabulary measure).

Materials. Participants completed the study on their own computer equipped with Zoom videoconference call software (Zoom Video Communications, Inc. 2024) as well as a webcam, microphone and headphones. A 10 min audio clip from "Guided Meditation Journey into Body Sensations" was retrieved from Top Form Fitness (2019). The clip played relaxing music and included specific guided instructions to focus attention on the sensations of the breath, sound, and the present moment. For the control condition, a 10 min audio clip from "Zen—Jerome Bixby" was retrieved from NewThinkable (2013). This provided peaceful auditory stimulation using a vocal delivery very similar to that of the mindful breathing clip. A static visual picture related to the audio content was displayed on screen for the duration of both auditory tracks.

The word retrieval test included 60 definitions stated in the form of a question, with a single term serving as the correct target word answer (e. g., *What is a professional* *map maker called?*, for which the correct response is *cartographer*; questions were from James et al. 2025). Participants answered each question with the word they believed to be the target, said that they did not know the word, or indicated if they had a TOT for the word. Each TOT was verified to be for our intended target word by re-presenting questions that elicited TOTs along with the correct answers at the end of the study, and the participant indicated whether or not the target was the word they had been trying to retrieve. Consistent with other experiments, we only retained TOTs for intended target words in our analyses.

A single question assessed participants' self-rated state mindfulness: *On a scale from 1–7, how mindful and present do you feel right now?* (1 = not at all mindful; 4 = neutral; 7 = extremely mindful). The question was presented immediately after the experimental manipulation and a second time right after the word retrieval task. A demographic form collected information regarding age, education, fluency in English, gender, race, and ethnicity. The Shipley (1940) Vocabulary Test was given along with several measures expected to relate to mindfulness and anxiety, including both forms of the State-Trait Anxiety Inventory (STAI; Spielberger 1983), the Kentucky Inventory of Mindfulness Skills (KIMS; Baer, Smith, and Allen 2004), and the Applied Mindfulness Process Scale (AMPS; Li, Black, and Garland 2016). The Mini Mental Status Exam (MMSE; Folstein, Folstein, and McHugh 1975) was given to assess the cognitive health of the older adults, and the MMSE was modified slightly to be administered over a videoconference call. A post-study questionnaire asked about the participant's meditation habits, whether the participant felt able to engage with the audio clip for their condition, and whether the participant was aware of the purpose of the study.

Procedure. The study was approved by our university's Institutional Review Board. Each participant was tested individually, via a Zoom call and Qualtrics (Qualtrics 2024). The participant was told to silence their cell phone and refrain from doing any distracting activities during the study. The participant wore headphones or earbuds so that they could clearly hear the clip played for them and turned on their camera to make the testing setting similar to an in-lab study.

Each participant was randomly assigned to a condition and was instructed to engage with the audio clip. The participant then completed the state mindfulness rating. Instructions for the word retrieval task included a definition of TOTs and explained that the participant should answer each question with the correct word, by indicating a TOT, or by saying they did not know the answer. To restrict hand gestures and ensure that the participant was not searching the internet for target word answers (e. g., on Google), the experimenter told the participant to hold an empty water bottle still with both hands in view of their camera throughout the word retrieval task, providing reminders as needed. The participant completed the second state mindfulness rating and indicated whether their reported TOTs were for the target word.

Immediately following this, the experimenter sent the participant a link to a Qualtrics survey where they completed the demographics form and other measures without the experimenter present. The KIMS, STAI-trait, STAI-state, and AMPS were presented to each participant in a random order. The participant then completed the Shipley vocabulary measure and the MMSE. Finally, the participant answered the post-study questionnaire and was debriefed and compensated.

Data scoring. Zoom sessions were recorded for later scoring and score checking. The data were scored according to the participant's initial response even if they provided more than one response (e. g., if someone said *Oh, TOT...wait, is it cartographer?*

No, I don't know, this was scored as a TOT). Correct responses included both leniently and strictly correct productions. For example, if a participant said *carteygrapher* for *cartographer*, it was considered correct. TOTs included only trials for which the participant endorsed the correct target word as the word they had in mind at the end of the study. The number correct and number of TOTs were divided by the number of trials and multiplied by 100 to create the dependent variables percent correct and percent TOTs.

2.2 Results and discussion

We first tested for age group differences in the inventories completed by participants in order to characterize our samples. Older adults had better scores on the vocabulary measure ($M = 40.11$; $SD = 11.76$) than did young adults ($M = 28.92$; $SD = 7.55$; four older and one young adult did not complete the vocabulary test), $t(161) = -17.13$, $p < .001$, $d = -2.68$, confirming that older adults' vocabulary was greater than young adults', as is typically found with the healthy samples tested in cognitive aging research. Young adults had higher scores on the KIMS ($M = 124.58$; $SD = 16.31$) than did older adults ($M = 119.20$; $SD = 13.42$), $t(166) = 2.34$, $p = .010$, $d = 0.36$, indicating greater trait mindfulness for young than older adults. On the other hand, older adults had higher scores on the AMPS ($M = 41.37$; $SD = 7.62$; one older participant did not complete this measure) than did young adults ($M = 35.79$; $SD = 8.46$), $t(165) = -4.48$, $p < .001$, $d = -0.69$, indicating greater engagement in mindfulness practices among older than young adults. Young adults had higher scores on the STAI-state measure ($M = 40.11$; $SD = 11.76$) than did older adults ($M = 28.92$; $SD = 7.55$), $t(166) = 7.34$, $p < .001$, $d = 1.13$, and similarly, young adults had higher scores on the STAI-trait measure ($M = 46.89$; $SD = 11.89$) than did older adults ($M = 32.51$; $SD = 8.88$), $t(166) = 8.88$, $p < .001$, $d = 1.37$, indicating greater state and trait anxiety for young than older adults. Post-manipulation state mindfulness self-ratings were analyzed in a 2 x 2 ANOVA (by experimental condition and age group, see Table 1). One older adult failed to complete the rating, so data from 83 older adults are included here.

Table 1: Means (and SDs) for self-rated mindfulness by age group and experimental condition, Experiment 1

	Age group	
	Young adults	Older adults
Condition		
Mindful breathing	5.60 (0.70)	5.49 (0.91)
Control	5.00 (1.08)	5.80 (0.76)

There was no main effect of condition, $F(1, 163) = 1.09$, $p = .298$, $\eta_p^2 = .007$, but there was a main effect of age group, $F(1, 163) = 6.52$, $p = .012$, $\eta_p^2 = .038$, qualified by a significant interaction of condition and age group, $F(1, 163) = 11.16$, $p = .001$, $\eta_p^2 = .064$. Young adult participants in the mindful breathing condition indicated feeling more mindful than those in the control condition, $t(82) = 2.99$, $p = .002$, Cohen's $d = -0.65$, whereas older adult participants in the mindful breathing condition indicated feeling *less* mindful than those in the control condition, $t(81) = -1.69$, $p = .048$, $d = 0.37$. Older adults rated themselves as feeling more mindful overall than young adults, and only young adults reported being more mindful in the mindful breathing condition than in the control condition.

We next compared percent correct responses in a 2 x 2 ANOVA (by experimental condition and age group, see Figure 1). There was a marginally significant main effect of condition, with participants in the mindful breathing condition producing marginally more correct responses than participants in the control condition, $F(1,\ 164) = 3.72$, $p = .055$, $\eta_p^2 = .022$. There was a main effect of age group, such that older adults produced more correct responses than young adults, $F(1,\ 164) = 129.04$, $p < .001$, $\eta_p^2 = .440$. There was no interaction of condition and age group, $F(1,\ 164) = 0.10$, $p = .749$, $\eta_p^2 = .001$, but the finding that only young adults' self-rated state mindfulness was higher in the mindful breathing than control group led us to explore whether the condition difference was obtained within each age group separately. Young adults produced more correct responses in the mindful breathing ($M = 29\,\%$; $SD = 14\,\%$) than control condition ($M = 24\,\%$; $SD = 12\,\%$), $t(82) = 1.72$, $p = .044$, $d = -0.38$, but older adults did not, $t(82) = 1.06$, $p = .146$, $d = -0.23$.

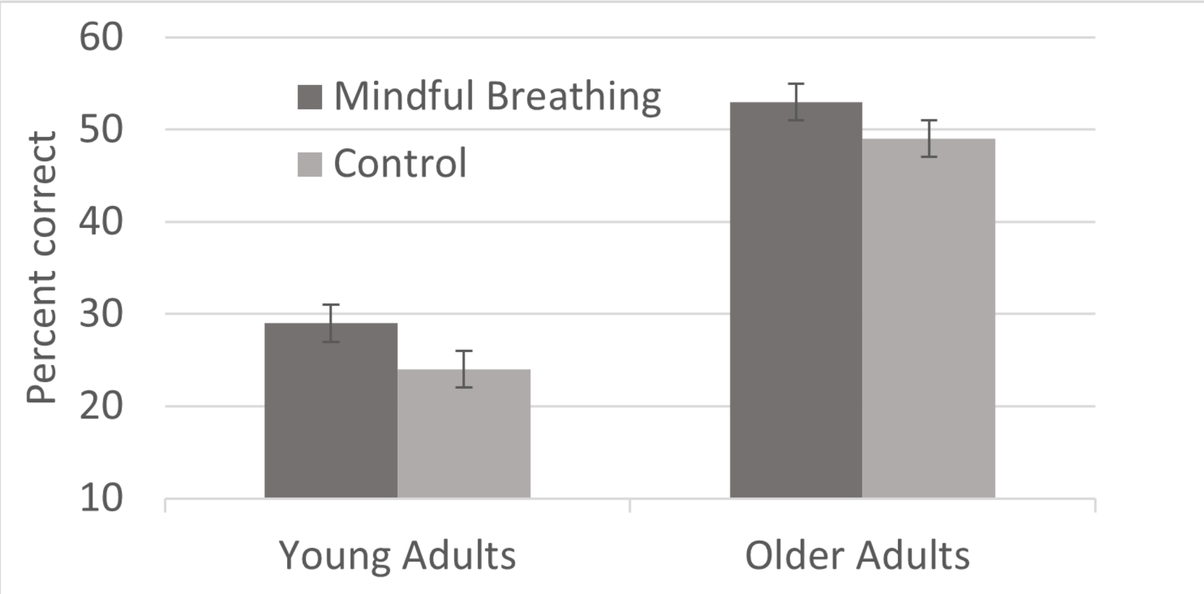

Figure 1: Means (± 1 SE) for percent correct responses by experimental condition and age group, Experiment 1

There was no main effect of condition, $F(1,\ 164) = 0.16$, $p = .693$, $\eta_p^2 = .001$, nor was there a main effect of age group, $F(1,\ 164) = 1.86$, $p = .175$, $\eta_p^2 = .011$. There was also no interaction of condition and age group, $F(1,\ 164) = 1.06$, $p = .305$, $\eta_p^2 = .006$. TOT rate did not vary systematically with condition or age group. Young adults did not have different TOT rates in the mindful breathing ($M = 10\,\%$; $SD = 6\,\%$) and control condition ($M = 11\,\%$; $SD = 7\,\%$; $t(82) = 1.07$, $p = .143$, $d = 0.23$, nor did older adults have different TOT rates in the mindful breathing ($M = 12\,\%$; $SD = 8\,\%$) and control condition ($M = 11\,\%$; $SD = 7\,\%$; $t(82) = -0.42$, $p = .336$, $d = -0.09$.

In terms of the post-study questions, 31 % of young adults and 48 % of older adults reported that they regularly or sometimes meditate. In terms of engagement with the intervention, 46 % of young adults and 42 % of older adults in the mindful breathing condition indicated that they effectively engaged in mindful breathing. Only 7 % of young and 7 % of older adult participants could accurately guess or report the specific purpose of the study. In summary, the age groups were generally similar on these measures. The finding that a larger proportion of older than young adults meditate is unlikely to explain any of our results.

Although only young adults' self-rated state mindfulness was higher for the mindful breathing than control group, the marginal main effect of condition on correct response rate indicates that overall, participants who performed the mindful breathing exercise had a slightly higher percent correct responses than people in the control condition, and our follow up analysis indicated that young adults' rate of correct responding was significantly higher in the mindful breathing than control group. This finding comports with Silver, James, and Small (2021)'s result that a brief mindful breathing exercise increased correct word production for young adults in a picture naming task. Our self-ratings of mindfulness show that older participants in the mindful breathing condition felt less mindful than those in the control condition, so it makes sense that older participants' word retrieval measures were not significantly better following a brief mindful breathing exercise than in a relaxing control condition.

Contrary to predictions, TOT rate was stable across all conditions. The percent of trials with TOTs for the target words did not differ between experimental groups nor did it differ between the age groups. The means suggest that neither floor nor ceiling effects for TOTs are responsible for the lack of predicted differences. This lack of age-related increase in TOTs is unfortunate but not unique (e. g., James and Burke 2000; James et al. 2025), and might result from our stimulus selection process. Because we used items shown in previous research to yield reasonably high numbers of TOTs for members of both age groups, we might have biased our study toward not finding age differences in TOT rate. However, this aspect of our methods cannot explain the lack of difference between the mindful breathing and control groups. Older adults' performance did not benefit from mindful breathing, possibly because the manipulation did not affect their overall degree of state mindfulness.

The experimental procedure we adopted due to COVID-19 might have affected the results. Originally, we planned to use a control condition similar to that used in Silver, James, and Small (2021)'s study. The experimenter was going to act like they forgot something in the other room and leave to look for the missing item. After 10 min of supposed searching, they were to come back to the room and finish the study. However, the need to use online testing procedures meant we had to select another control condition. We opted to select a story presented in a relaxing voice for our control condition, and the resulting increased similarity between the experimental and control conditions may have yielded a weaker manipulation than that used in Silver, James, and Small (2021).

3 Experiment 2

This experiment followed up Experiment 1 to determine if the results would replicate for young and older adults in a different type of word-retrieval task: naming public figures from their photographs. The basic information about Experiment 2 was preregistered on ClinicalTrials.gov (NCT05550779), consistent with the reporting requirements for the funding mechanism at that time. Although average TOT rates in Experiment 1 were sufficient to avoid floor effects, we reasoned that the typical higher TOT rates found during attempts to retrieve proper names (e. g., James 2006) would allow a better test of possible TOT rate reduction due to mindful breathing. In the TDH model, names are harder to learn and retrieve than other types of words for several reasons (e. g., names are lower in frequency and do not have any inherent meaning), and they are therefore represented slightly differently than other types of words (e. g., James 2006). However, deficits in priming transmission work the same way for all word types, and for both names and other words, TOTs are caused by failed access to phonology. Other than the type of naming task, the methodology was very similar to Experiment 1, with a few modifications. In Experiment 2, we played a different 10-min segment of the mindful breathing exercise to strengthen the manipulation. We obtained familiarity judgments from each participant for each celebrity stimulus photo to allow customization of the stimulus set by excluding stimulus photos with which each participant was unfamiliar. We did not administer all measures from Experiment 1 and instead gave the Mindful Attention Awareness Scale (MAAS; Brown and Ryan 2003). We used a variety of calculations of the dependent measure of TOTs, following methods recommended by other researchers (e. g., Gollan and Brown 2006).

Although Experiment 1 data did not support all predictions, we retained those predictions in this new, improved experiment. Specifically, we expected that TOTs would decrease, and correct responses would increase, following a mindful breathing exercise compared to a control condition. We further expected to find a similar degree of facilitation following mindful breathing for participants from both age groups.

3.1 Method

Participants. The desired sample size was determined based on the medium-sized effect reported by Silver, James, and Small (2021) (these data were not available when Experiment 1 begun). G*Power was used to determine the required number of participants to ensure adequate power for detecting a medium-sized effect ($d = 0.50$), with alpha set to .05 and power to .80. The necessary sample size was 51 young and 51 older adults.

Young and older adult participants were primarily recruited via Research Match, a National Institutes of Health funded platform for participant recruitment in the United States. Additional young adults were recruited from our university's Sona system and compensated with extra credit and older adults were recruited from the Gerontology Center volunteer list and compensated with a $15 electronic gift certificate. Some young adults' data were excluded due to having distractions present (n = 2), experiencing a poor internet connection leading to the inability to complete the study (n = 2), being unwilling to use video during testing (n = 1), or not meeting the age inclusion criteria after initially claiming that they did (n = 2). These data were excluded prior to analyses, yielding a final sample size of 102 (51 young and 51 older adults).

Forty-two young participants identified as female, 8 as male, and 1 as other gender. Thirty-one people identified as white, 7 as more than one race, 3 as Black or African American, 7 as Asian, 2 as American Indian/Alaska native, and 1 did not indicate their race. Six people indicated their ethnicity as Hispanic or Latinx. Their mean age was 23.96 ($SD = 5.12$; range of 18–35) and they had completed a mean of 15.34 years of education ($SD = 2.64$; 1 young adult did not report years of education).

Thirty-nine older participants identified as female, 12 as male, and none as other gender. Fifty people identified as white and 1 as Black or African American. No one indicated their ethnicity as Hispanic or Latinx. Their mean age was 67.33 ($SD = 5.86$;

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range of 60–80) and they had completed a mean of 16.65 years of education (*SD* = 2.51). All participants reported speaking fluent, native English as well as residing in the United States for at least five years (to ensure at least some familiarity with the pictured public figures).

Materials and procedure. These were similar to Experiment 1. A different 10 min segment of the "Guided Meditation Journey into Body Sensations" that included more guided breathing instruction during the clip was selected to strengthen the manipulation. The single question assessing how mindful and present participants felt was reworded to *On a scale of 1–4, how mindful do you feel right now?* (1 = not at all mindful and 4 = very mindful) and the researcher defined mindfulness for them: "Being mindful is a state of mind in which you are fully present, aware of where you are and what you are doing and not reactive or overwhelmed with what's going on around you or intrusive thoughts." The MAAS has 15 items to which participants responded using a Likert scale from 1 (*almost always*) to 6 (*almost never*).

The dependent measure was a name retrieval task that included 83 photographs of public figures, including actors, politicians, musicians, and athletes. Each picture consisted of a close-up image of the person, to which the participant was asked to produce the person's name, say they did not know the person's name, or say they were experiencing a TOT (defined as in Experiment 1). After the naming task, all public figure images were re-presented along with their names and participants were asked *How familiar are you with the person in this picture?* They responded on a scale from 1 (not at all familiar) to 4 (very familiar). Each participant also completed a post-study questionnaire which asked about their meditation habits and their perception of the purpose of the study and completed a demographics questionnaire and the MAAS.

Data scoring. Data were scored as in Experiment 1, but percentages were calculated out of the number of stimuli that a participant rated a 3 (*familiar*) or 4 (*very familiar*) during the familiarity task (rather than all trials). In other words, trials for which a participant reported not being familiar with the pictured public figures were dropped prior to analyses. Also, TOT rates were calculated in two additional ways:

1. Following Gollan and Brown (2006), the percentage TOT of known stimuli was calculated by dividing the number of TOTs out of the number of correct or TOT responses[1] and

2. following James and Burke (2000), the percentage TOT of unknown stimuli, calculated by the number of TOTs out of the number of trials minus the number of correct responses.[2]

These scores have all been used in previous research and reflect different researchers' positions on the appropriate computations for assessing TOT incidence.

3.2 Results and discussion

We first tested for age group differences in the MAAS measure of trait mindfulness. Older adults had higher scores on the MAAS ($M = 4.44$; $SD = 0.62$) than did young adults ($M = 3.81$; $SD = 0.67$), $t(100) = -4.95$, $p = .010$, $d = -0.98$, indicating greater trait mindfulness for our sample of older than young adults.

1. [# TOT / (# TOT + # strictly correct)] x 100]
2. [# TOT / (# trials - # strictly correct) x 100]

We analyzed post-manipulation self-reported state mindfulness in a 2 x 2 ANOVA (by experimental condition and age group, see Table 2). There was no main effect of condition, $F(1, 98) = 2.77$, $p = .10$, $\eta_p^2 = .03$; ratings in the mindful breathing condition ($M = 3.35$, $SD = 0.59$) were not higher than in the control condition ($M = 3.16$, $SD = 0.73$). There was a main effect of age group, $F(1, 98) = 14.77$, $p < .001$, $\eta_p^2 = .13$, indicating a difference between young adults' ($M = 3.02$, $SD = 0.68$) and older adults' ($M = 3.49$, $SD = 0.58$) self-reported state mindfulness ratings. There was no interaction between condition and age, $F(1, 98) = 1.42$, $p = .24$, $\eta_p^2 = .01$, but to determine if the pattern was similar to the ratings in Experiment 1, we examined each age group separately. Young adult participants in the mindful breathing condition indicated feeling more mindful than those in the control condition, $t(49) = 1.90$, $p = .031$, $d = -0.53$, whereas older adult participants' ratings did not differ between the mindful breathing and control conditions, $t(49) = 0.36$, $p = .36$, $d = -0.10$.

Table 2: Means (and SDs) for self-rated mindfulness by experimental condition and age group, Experiment 2

	Age group	
	Young adults	Older adults
Condition		
Mindful breathing	3.19 (0.57)	3.52 (0.59)
Control	2.84 (0.75)	3.46 (0.58)

The effect of the mindful breathing exercise on correct responding for young adults obtained in Experiment 1 suggested that we should examine those data for this experiment. When we registered this experiment on ClinicalTrials.gov, we did not indicate that we would analyze correct responses, so this analysis is exploratory. We compared percent correct in a 2 x 2 ANOVA (by experimental condition and age group, see Figure 2). There was no main effect of condition, $F(1, 98) = 1.89$, $p = .172$, $\eta_p^2 = .019$, and there was no main effect of age group, $F(1, 98)$, $\eta_p^2 = 1.60$, $p = .208$, $\eta_p^2 = .016$. There was also no interaction between condition and age group, $F(1, 98) = 0.21$, $p = .652$, $\eta_p^2 = .002$, but the finding that only young adults' self-rated state mindfulness was higher in the mindful breathing than control group led us to further explore whether the condition difference was obtained within each age group separately, as we did in Experiment 1. Young adults did not produce significantly more correct responses in the mindful breathing than control condition, although the data trended that way, $t(49) = 1.39$, $p = .086$, $d = -0.39$, but this trend was not even approaching significance for older adults, $t(49) = -0.61$, $p = .271$, $d = -0.17$.

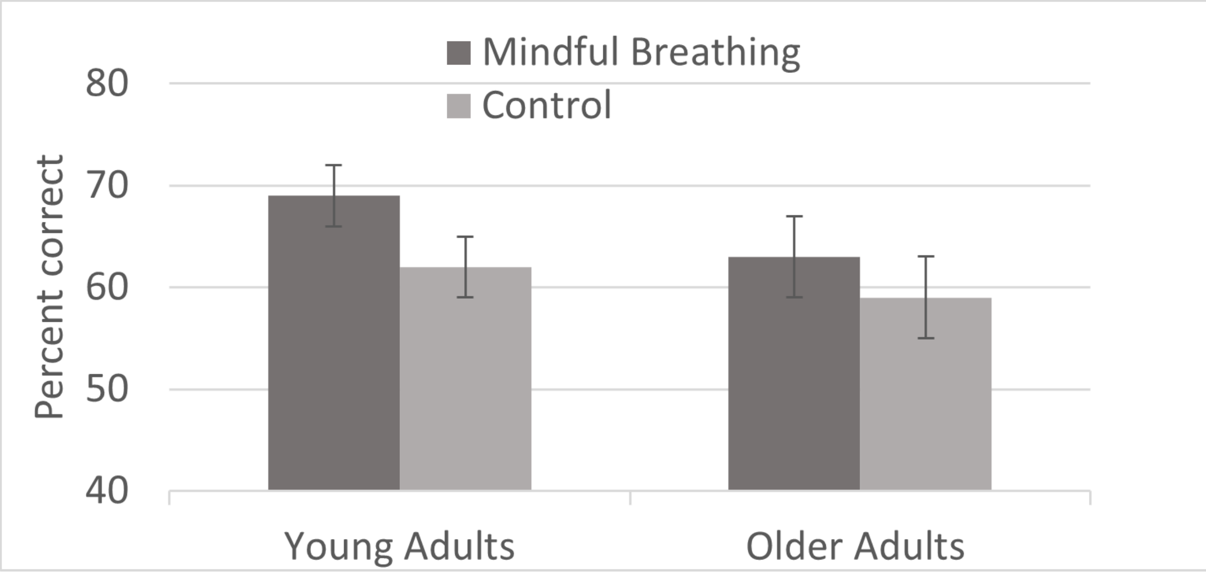

Figure 2: Means (± 1 SE) for percent correct responses by experimental condition and age group, Experiment 2

We next compared percent of familiar faces with TOTs in a 2 x 2 ANOVA (by experimental condition and age group, see Table 3). There was no main effect of condition, $F(1, 98) = 0.41$, $p = .525$, $\eta_p^2 = .004$, no main effect of age group, $F(1, 98) = 0.30$, $p = .584$, $\eta_p^2 = .003$, and no interaction of condition and age group, $F(1, 98) = 0.12$, $p = .731$, $\eta_p^2 = .001$. Next, we compared percent of known faces with TOTs[3] in a 2 x 2 ANOVA (by experimental condition and age group, see Table 3). Again we found no main effect of condition, $F(1, 98) = 0.12$, $p = .914$, $\eta_p^2 < .001$, no main effect of age group, $F(1, 98) = 1.07$, $p = .303$, $\eta_p^2 = .011$, and no interaction of condition and age group, $F(1, 98) < 0.01$, $p = .971$, $\eta_p^2 < .001$. A final 2 x 2 ANOVA tested the effect of experimental condition and age group on the percent of TOTs of the unknown stimuli[4] (see Table 3). There was again no main effect of condition, $F(1, 98) = 0.92$, $p = .339$, $\eta_p^2 = .009$, no main effect of age group, $F(1, 98) = 0.40$, $p = .530$, $\eta_p^2 = .004$, and no interaction of condition and age group, $F(1, 98) < 0.01$, $p = .989$, $\eta_p^2 < .001$ (Table 3).

On the post-study questions, 36 % of young adults and 45 % of older adults reported that they regularly or sometimes meditate. In terms of intervention engagement, 43 % of young adults and 42 % of older adults in the mindful breathing condition indicated that they effectively engaged in mindful breathing. Only 8 % of young and 2 % of older adults accurately reported the specific purpose of the study. In summary, the age groups were generally similar on these measures. The finding that a larger proportion of older than young adults meditate is unlikely to explain any of our results, but does replicate this finding from Experiment 1.

3. [TOTs / (TOTs + correct) x 100]
4. [TOTs/(# familiar trials - number correct) x 100]

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Table 3: Means (and SD) percent of trials with TOTS by experimental condition and age group, Experiment 2

	Age group	
	Young adults	Older adults
Condition		
TOTs % familiar trials		
Mindful breathing	15.55 (13.57)	17.75 (14.30)
Control	14.83 (9.13)	15.33 (11.97)
TOTs as % Known		
Mindful breathing	20.31 (18.12)	24.06 (19.16)
Control	20.82 (13.10)	24.31 (19.41)
TOTs % unknown		
Mindful breathing	41.45 (22.17)	38.52 (24.89)
Control	37.02 (24.54)	34.22 (19.89)

As in Experiment 1, following the intervention, only young adults' self-rated state mindfulness was higher for the mindful breathing than control group. Unlike Experiment 1, there was no main effect of condition on correct response rate in this study. Participants who performed the mindful breathing exercise did not have a different rate of percent correct responses than people assigned to a relaxing control condition. Also contrary to predictions, TOT rate was stable across all conditions. The percent of trials with TOTs for the target words did not differ between experimental groups nor did it differ between the age groups using any of the TOT calculations recommended in the literature. The means indicate that neither floor nor ceiling effects for TOT rate are responsible for the lack of predicted differences. The lack of age-related increase in TOTs is surprising given previous findings about age-related increases in TOTs for proper names (e. g., James 2006), but as in Experiment 1, this might result from our stimulus selection process. Additionally, the use of only stimuli with which an individual participant was familiar (i. e., customizing each participant's stimulus set) could have altered the results, but seems unlikely to have caused the lack of effect of experimental condition on TOT rate.

4 General discussion

Findings from our two experiments suggest that although a brief mindful breathing exercise improved non-name word retrieval success in young adults, it did not improve retrieval of names of familiar faces, nor did it reduce the number of TOTs experienced by adults from either age group. This single finding of a benefit of mindful breathing within the two experiments did not replicate in Experiment 2, so should be treated cautiously. Inasmuch as young adults' improvement in correct non-name word retrieval occurred without a corresponding reduction in TOTs, facilitation appears to be at the level of lexical access rather than phonological access. This comports with the findings of Silver, James, and Small (2021), who found that correct picture naming increased in young adults following a similar mindful breathing intervention. Results overall do not support the speculation that mindful breathing can facilitate system-wide priming transmission. We expected that mindful breathing would reduce stress and anxiety compared to a control condition, in turn increasing transmission of priming, with similar benefit for young and older adults. This hypothesis was based on the suggestion of James et al. (2018) that anxiety reduces priming transmission. We therefore reasoned that mindful breathing, via its ability to reduce anxiety, could improve priming transmission and thereby reduce TOTs. Results do not support this hypothesis and indicate the possible need for theoretical refinement. Alternately, the finding that older adults' performance did not benefit from mindful breathing could be because the manipulation did not affect their overall degree of state mindfulness (as evidenced in their self-ratings) or their anxiety levels. Perhaps older adults have shown benefits of longer-term mindfulness interventions (e. g., Lenze et al. 2014; Mallya and Fiocco 2016) because they require more time to deeply engage with the intervention, although our older participants did self-report effective engagement similar to young adults'. In terms of practical application, taking the time to engage in a quick and easy mindful breathing exercise might benefit word retrieval for young adults, but older adults do not show any such benefit above and beyond listening to a calmly presented story.

This is, of course, not a clear indictment of mindful breathing exercises in general. Our studies used a single type of mindful breathing exercise, for a very brief period, and compared it with a control condition that might also promote relaxation. This adheres to procedures used in other research on mindfulness interventions, but it could be argued that a neutral control condition or even an anxiety-provoking condition would be a more appropriate comparison to reveal benefits of mindful breathing. Our manipulation checks showed that young participants in the mindful breathing condition felt more mindful than those in the control condition, so a stronger manipulation of mindfulness could reveal additional beneficial effects on word retrieval performance, perhaps even for older participants. We did not measure self-reported anxiety immediately following the manipulation, so even though young adults reported increased mindfulness, we cannot be certain whether the mindful breathing task reduced self-reported anxiety. Alternately, the specific type of the stress or anxiety caused by evaluative observation may be unaffected by mindful breathing exercises. Finally, our null results could be interpreted as an indication that brief mindful breathing exercises have limited effectiveness in improving performance on cognitive tasks. Other recent high-powered, well-designed experiments have failed to find benefits of mindful breathing for working memory performance as measured by span tasks (Quek et al. 2021) or for attentional tasks involving inhibitory processes or task switching (Hartanto et al. 2023) and there may be untold numbers of unpublished studies which did not obtain any benefit of mindful breathing on cognitive performance.

The experimental procedure we adopted due to COVID-19 might have affected the results. Originally, we planned to use same control condition as used in Silver, James, and Small (2021)'s study. The experimenter was going to pretend they forgot something in another room and leave for 10 min before returning to finish the study. However, the necessity of using online testing procedures during the pandemic meant we needed to devise another control condition. We opted to select a story presented in a relaxing voice as our control condition, and this increased similarity may have yielded a weaker manipulation than that of Silver, James, and Small (2021). Increasing the amount of time spent doing the mindful breathing exercise might yield a stronger manipulation that would yield differences in word retrieval performance between groups, and future research should test that possibility.

We designed these studies to test whether a brief intervention—the very type of thing someone might choose to do before a difficult task, such as a job interview—could be beneficial. The question of whether other mindful breathing exercises, delivered in person (instead of online), for a longer period of time, or with extensive pre-training might offer some benefit remains open. Nevertheless, our research provides ecologically valid and methodologically sound empirical evidence suggesting limited usefulness of mindful breathing as a quick and easy way to improve word retrieval for young adults, with no evidence of any benefit for older adults. These experimental results contribute to a greater understanding of language processing in aging by examining how non-linguistic factors (in this case, mindful breathing exercises) affect word retrieval in younger and older adults. Our findings of minimal-to-no benefits will guide refinement of existing theories and inform future research examining language processing in aging.

Author contributions

All authors contributed to the experimental designs, data scoring, statistical analyses, and writing of the manuscript. Experiment 1 contains elements of David Van Wagenen's undergraduate honors thesis project and Experiment 2 contains elements of Hannah Levitt's MA thesis project.

Ethics statement

These experiments were approved by the Institutional Review Board at the University of Colorado Colorado Springs (www.uccs.edu/IRB), protocols #20-005 ("What makes people better at retrieving difficult words?") and #23-023 ("What makes people better at retrieving names of famous people?").

Conflict of interest

None for any author.

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