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Augmenting behavioural activation with mental imagery improves post-stroke depressive symptoms

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ABSTRACT

Depression affects approximately 30% of stroke survivors. Behavioural activation (BA) is a depression intervention based on completing positively reinforcing activities. However, post-stroke cognitive changes, like episodic memory difficulties, could affect encoding, storing, and recollecting reinforcing activities. Mental imagery has high acceptability in post-stroke motor recovery interventions, and in depression and anxiety interventions outside of stroke. We evaluated whether augmenting BA with mental imagery improves mood and activity outcomes in stroke compared to BA alone. Randomized participants received positive activity scheduling ("standard" BA) with (1) mental imagery simulating the planned activity, or (2) an imagery active control unrelated to the planned activity. Depressive symptoms and activity measures were completed weekly over 3 sessions and between-group differences evaluated via mixed-effects modelling. Exploratory models covaried for baseline verbal episodic memory and subjective memory. N = 45 participants [*M* age = 69.29, *M* years post-stroke = 3.00, 60% male] took part. BA with mental imagery led to significantly greater reduction in depressive symptoms compared to standard BA ($t_{(79)} = -2.72$, $p = .008$; Cohen's $d = 0.65$). Subjective, but not objective, memory correlated with depression severity and activity engagement. There were no between-group differences in activity measures. Mental imagery may enhance mood outcomes in BA post-stroke, potentially supporting positive activity reflections irrespective of activity completion.

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KEYWORDS
Stroke; Depression; BA; imagery; memory.

Introduction

Up to a third of stroke survivors experience depression within the first five years following a stroke (Hackett & Pickles, 2014, Kusec et al., 2023b), that negatively

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impacts post-stroke quality of life. Behavioural activation (BA) is an evidence-based behavioural therapy encouraging individuals to plan and engage in positively-reinforcing, enjoyable activities (Lewinsohn, 1975). BA is often the intervention of choice in neurological populations; its straightforward premise is acceptable in adults with acquired neurological conditions (Kusec et al., 2023a). Previous trials with adults with a range of neurological conditions have demonstrated clinically meaningful improvements in depression (Kusec et al., 2023c; Oates et al., 2020; Thomas et al., 2013; 2019). Further, BA is more cost-effective than talking therapies such as Cognitive Behavioural Therapy, due to reduced need for highly specialist clinicians, and with comparable benefits (Finning et al., 2017; Richards et al., 2016). BA has further been shown to be as effective as first-line antidepressants in a non-stroke population of adults with depression (Dimidjian et al., 2006). A systematic review and meta-analysis of five randomized controlled trial of BA for stroke survivors found that BA was associated with reduced post-stroke depression symptom severity at 6-month follow-up, with a moderate effect size (Hedges' $g = -.39$: Yisma et al., 2024). Further, a feasibility study found BA for post-stroke depression can be delivered by junior mental health professionals (Thomas et al., 2019). Taken together, BA is an effective, accessible, and scalable treatment option for post-stroke depression.

The core feature of BA, activity scheduling, requires both the prospective planning and execution of, and retrospective reflection on, enjoyable activities (Cuijpers et al., 2007). Memory plays a central role in remembering how, when, and whether enjoyable activities were completed (Tomaszewski Farias et al., 2009) – emphasizing the memory demands of activity scheduling. This is problematic in the context of post-stroke depression, because at least some type of memory impairment affects at least 20% of individuals six-months-post stroke (e.g., Demeyere et al., 2019; Milosevich et al., 2024) and up to 31% one year after stroke (Snaphaan & de Leeuw, 2007). Stroke survivors report feeling depressed and frustrated by these memory difficulties (Pappadis et al., 2018), with memory difficulties identified as a long-term concern in approximately 43% of stroke survivors that negatively impacts quality of life in patient reports of unmet need (Kim et al., 2021; McKevitt et al., 2011). The effectiveness of activity scheduling as part of BA partially relies on both explicit (e.g., intentional storage of activity-relevant information) and implicit (e.g., procedural memory for previously acquired abilities relevant to an activity) memory processes, which may pose challenges for individuals with poor memory. It is therefore essential to investigate whether BA can be augmented to enhance its efficacy for stroke survivors who may have memory difficulties.

Outside of stroke, depression has been shown to have a bi-directional relationship with episodic memory: a long-term declarative memory process involved in recalling event details (Airaksinen et al., 2007; Baddeley, 1992). One key mechanism underlying this relationship is the "negative-recall bias," wherein individuals with depression demonstrate greater difficulty recalling

positive stimuli compared to negative stimuli. This effect becomes more pronounced at an age range associated with an increased risk of stroke ($M \geq 55$ years: James et al., 2021; Feigin et al., 2022). The theory underpinning BA assumes that depression and reduced participation in positively reinforcing activities mutually sustain one another: low mood can lead to decreased energy, leading to avoidance of pleasurable activities, social isolation, further reduction in mood, and so on (Ekers et al., 2014). The ability to recall and reflect on the positive reinforcement derived from planned activities is thought to be a cognitive strategy to interrupt this vicious cycle. Empirical evidence supports the notion that BA can reduce negative affective recall compared to a non-BA control group (Ruzickova et al., 2023). Additionally, individuals with brain injury and depression exhibit significantly reduced positive biases in prospective cognition compared to both non-injured controls and non-depressed controls with brain injury (Murphy et al., 2019). Together, this suggests that augmenting BA with an episodic memory enhancement technique could optimize the positive reinforcement gained from BA, either prospectively or retrospectively, thereby enhancing its benefits for stroke survivors with low mood with episodic memory difficulties.

Typically, post-stroke depression interventions investigate the clinical effectiveness of "packaged" multicomponent interventions (Lee et al., 2021). BA can comprise a range of techniques, including activity scheduling, mood monitoring, procedures targeting behavioural avoidance, skills training, and more (Kanter et al., 2010), and has been evaluated in stroke and brain injury across customized multisession interventions packages (Thomas et al., 2019; Oates et al., 2020; Kusec et al., 2023c). Though there is rationale to incorporate multiple BA-based techniques to enhance overall intervention success, there is benefit in evaluating whether the core feature of BA – namely, activity scheduling – can be augmented to offset episodic memory demands. This provides a rationale for conducting a brief, controlled investigation aimed at isolating an agent of change in this relationship between post-stroke episodic memory difficulties and depression severity.

One possible technique that could enhance episodic memory in activity scheduling BA is mental imagery (MI): mentally simulating activities in the mind's eye as more vivid and realistic than verbal thought (Mathews et al., 2013). Outside of stroke, mentally pre-rehearsing enjoyable activities has been shown to enhance memory for activity planning amongst adults with depression (Pile et al., 2021) and increases self-reported motivation for rewards in individuals with depression (Renner et al., 2021). This suggests that mental imagery in the context of BA could indirectly enhance a positive reinforcement derived from activities, thereby alleviating depression in line with the theoretical framework of BA (Lewinsohn, 1975). Such indirect enhancement may occur due to mental imagery increasing the likelihood of engaging in the planned activities. Recent evidence increasingly supports MI as a technique to enhance mood outcomes in

BA outside of stroke. Renner et al. (2017) found that BA augmented with MI resulted in greater reductions in depression severity relative to BA with a non-imagery control. In a subsequent study, Renner et al. (2019) compared three conditions: BA with motivational MI; BA with a verbal reminder to complete the activity; and standard BA as a non-imagery non-reminder control. BA with motivational MI led to higher activity completion rates and the greatest increase in self-reported reward, outperforming both control conditions. Furthermore, a randomized controlled trial of BA paired with MI in older adults (M age $\geq$ 65 years) reported greater reductions in depression severity compared to an activity attention control, with a large effect size (Hedges' $g = .85$: Pellas et al., 2022).

Engaging in guided MI sessions has been shown to act as an effective compensatory strategy to help adults with mild cognitive impairment complete activities (Cheng et al., 2021). Imagery processes have been shown to be well-preserved in neurological populations including stroke (Kho et al., 2014; Syed et al., 2020). MI has been shown to be feasible for stroke survivors with aphasia (Laures-Gore et al., 2021). Taken together, these findings suggest that MI could serve as a viable technique to augment BA for stroke survivors. However, to the best of our knowledge, no research has yet directly examined the effects of augmenting BA with MI in a stroke population in terms of mood and activity benefits.

This study aimed to compare two sessions of behavioural activation (BA) augmented with or without mental imagery (MI) at reducing depression severity – the primary outcome. The study design and hypotheses were pre-registered (12/04/2023) on the Open Science Framework: https://osf.io/bzu5h.

Hypothesis one

Participants in the behavioural activation plus mental imagery (BA + MI) condition will demonstrate a significantly greater reduction in depressive severity than participants in the behavioural activation plus active control (BA + AC) condition.

Hypothesis two

Participants in the BA + MI condition will demonstrate a significantly greater engagement in reinforcing activities than participants in the BA + AC condition.

Materials and methods

Sample

A priori power analysis

An a priori sample size calculation was performed using a simulated mixed-effects linear model with anticipated fixed and random effects. An effect size

estimate of Cohen's $d = 0.50$ was used, lowered from a similar study of BA with MI in older adults without stroke ($d = 0.58$: Pellas et al., 2022) to accommodate for stroke population heterogeneity (Muir, 2002). This estimated effect size aligns with a systematic review of BA efficacy ($d = 0.24–1.17$ among stroke survivors; Oates et al., 2020).

Using data sent by the corresponding author, change in depression severity was simulated based on the Pellas et al. (2022) baseline and post-experiment (4-week) means, and standard deviations as measured using the Patient Health Questionnaire-9 (PHQ-9: Kroenke et al., 2001). To account for an exploration into the effect of episodic memory abilities on outcomes, this simulated model covaried for episodic memory ability using a previously estimated correlation between episodic memory and mood (Pearson's $r = .16$: Kelleher et al., 2024).

Following simulations, a minimum sample of $N = 50$ was identified to sufficiently detect a between-group effect size of .50 (beta = 0.80, alpha = .05).

Ethical approval

The University of Oxford Central University Research Ethics Committee granted ethical approval (REF: R85209/RE001). All participants provided informed consent.

Participant recruitment

Using opportunity sampling, stroke survivors previously consenting to be contacted by the Translational Neuropsychology Laboratory (National Research Ethics Committees REC reference 18/SC/0550) were called to determine eligibility.

Eligibility and screening

Following an initial study summary and screening consent procedure, potential participants were assessed for eligibility. Participants were eligible if they were aged 18 years or older, had a medical diagnosis of stroke, were at least 6-months post-stroke, and had a Patient Health Questionnaire – 9 (PHQ-9) score of 5 or higher at screen and Session 1 (indicating at least mild depression). The eligibility criteria also included having capacity to provide informed consent, the ability to speak and understand English, and the ability communicate via telephone.

The exclusion criteria included a Vividness of Visual Imagery Scale (VVIQ) of less than 40 at screen (indicating an inability to mentally simulate imagery), and a diagnosis of neurodegenerative disorder (e.g., dementia). Active suicidality (i.e., disclosure of a plan to end their life they intended to act upon) was also an exclusion criterion.

To correctly stratify proportions of those with and without memory impairment across the study conditions when conducting randomization, eligible participants also completed a verbal episodic memory test at screen (Wechsler Memory Scale III Logical Memory Test-I, see materials section).

Design

A two-arm randomized experimental investigation compared two sessions of standard BA with either: an active control (BA + AC) or guided prospective mental imagery simulating the activity planned in BA (BA + MI). The study had three sessions overall per participant.

The active control was a time-matched, guided session of non-activity focused MI (Aycock et al., 2018). This aimed to isolate activity scheduling augmented with "activity-focused mental imagery" as the experimental manipulation of interest. This was chosen to control for non-specific therapeutic factors such as empathy and time spent with a facilitator, which are especially important in experiments with older adult participants (LaFave et al., 2019).

Patient and public involvement (PPI)

Prior to study recruitment, the study protocol was discussed and conducted with an adult stroke survivor in Oxfordshire to evaluate appropriateness and reception from the target population. The protocol was deemed appropriate, enjoyable, and not overly fatiguing after minor changes were made (Supplemental Materials).

Materials

Screening materials

Participants completed the below measures at screen.

Patient Health Questionnaire – 9 (PHQ-9). This nine-item questionnaire measured depression severity (Kroenke et al., 2001), with questions like "In the past two weeks, how often have you been bothered by feeling down, depressed, or hopeless?" It is on a 4-point Likert scale totalling up to 27 points, where higher scores indicate greater depression severity. Internal consistency in the stroke population is high ($\alpha = .78$: Dajpratham et al., 2020). In-person and telephone administrations by junior mental health professionals highly correlate ($r = .84$: Kroenke et al., 2001). While the somatic symptoms of stroke (e.g., sleep disturbances) may overlap with somatic symptoms of depression, the PHQ-9 has demonstrated high criterion validity in stroke populations (de Man-van Ginkel et al., 2015). Further, the PHQ-9 maintains a unidimensional factor structure, consistent across stroke and non-stroke populations (Blake et al., 2025), and the influence of somatic symptoms

associated neurological conditions (including stroke) negligibly impact the PHQ-9 (Katzan et al., 2021).

Vividness of Visual Imagery Questionnaire (VVIQ). The VVIQ (Marks, 1973) measured mental imagery ability to identify ineligible participants with aphantasia. The VVIQ asks participants to quantify how vividly they can imagine things like a rising sun, and a familiar shop. Higher scores indicate more vivid mental imagery, up to a maximum 80 of points. The VVIQ demonstrates high internal consistency, and strong unidimensional factor structure (α = .88: Marks, 1973).

Logical Memory Test I – Wechsler Memory Scale – 3rd Edition (LMT). The Logical Memory Test (LMT; Wechsler, 1997) is a two-part, age-relative objective measure of verbal episodic recall memory. Participants are read two stories (α = .76 and .83: Tavakoli et al., 2011) in sequence, each with 25 components, and are asked to immediately recall each story separately. More components remembered indicates better episodic memory (maximum of 50 points). Scores in the bottom 5th percentile for one's age indicate impairment (Pereiro et al., 2021).

Study session materials

Eligible participants completed the PHQ-9 and the following at Session 1:

Behavioural Activation for Depression Scale – Short Form (BADS-SF). Activity engagement was measured using the BADS-SF, demonstrating high internal consistency (α = .89) and a reliable factor structure (Manos et al., 2011). It asks participants to endorse nine statements like "In the past week, I was an active person and accomplished the goals I set out to do," on a 7-point Likert scale totalling 54 points, with higher scores indicating greater engagement. This refers to participation in all activities generally across the week.

Everyday Memory Questionnaire – Revised (EMQ-R). Perception of everyday memory difficulties was measured using the 13-item EMQ-R, with high internal consistency (α = .92), a reliable factor structure, and good discriminatory validity between neurological populations (stroke and multiple sclerosis) and healthy controls (Royle & Lincoln, 2008). The measure asks about the frequency in the past month of 13 statements, like "having to check whether you have done something you should have done" on a 5-point Likert scale totalling 65 points, where higher scores indicate worse memory. This measure was included to assess subjective memory, which often differs from objective measures of memory in stroke (Hun Sung et al., 2023).

Randomization

Stratified randomization ensured equal proportions (1:1) of participants with episodic memory impairments (bottom 5th percentile on LMT) were allocated to each condition. Randomization was conducted in pre-determined block sizes of varying lengths by a researcher not involved in data collection. Varying block lengths were used to prevent the researcher delivering the

protocol guessing allocation sequence. Allocation was concealed using pre-prepared opaque envelopes.

Procedure

Session 1 was an in-person home visit in the community. First, baseline measure data was collected as described above. Then, participants were provided information about BA (with visual aids) with the opportunity to ask questions. The researcher then completed an activity scheduling exercise with the participant, helping identify and plan an activity (with a non-exhaustive activity list to help generate ideas). After confirming the planned activity and planning when to complete it, the researcher opened the envelope containing pre-determined randomization to a condition. So, the researcher collecting data was then unblinded. If participants were randomly allocated to the BA + MI condition, then they were provided information about MI in the context of BA with visual aids with the opportunity to ask questions. Participants completed a one-minute non-activity-focused imagery exercise adapted from the VVIQ as an imagery practice. Then, a five-to-seven-minute guided prospective mental imagery exercise was conducted, adapted from Renner et al. (2021), focusing on imagining completing the participant's planned activity, with two prompts throughout. Alternatively, if participants were randomly allocated to the BA + AC condition, then they were told MI would be used as a wind-down exercise after the activity scheduling and completed the same one-minute non-activity focused imagery exercise practice. However, participants were then instead tasked with mentally imagining a series of objects, one at a time, from a list of objects previously rated as emotionally neutral (e.g., a traffic cone: Pugh, 2022) for five-to-seven-minutes, with two prompts throughout. Regardless of condition allocation, Session 1 ended with one reminder to complete the planned activity at the planned time.

Session 2, for both conditions, occurred one week after Session 1 over the telephone. Participants completed the PHQ-9, the BADS-SF, and were asked whether they completed their planned activity (yes/no). Then, the same protocol from Session 1 for either BA + MI or BA + AC, with respect to the activity planning and their specific imagery exercise, was carried out. The activity they planned did not need to be the same as that planned in session 1.

Session 3 consisted of a telephone call one week after Session 2 collecting the PHQ-9, BADS-SF, and planned activity completion measures. Participants were then debriefed and thanked again for their time.

The protocol was delivered by two of the named authors (KK and AK): a master's student, and a post-doctoral researcher in neuropsychology. Only one researcher delivered the protocol in full for each participant. Protocol adherence was monitored during supervision with the postdoctoral researcher, supported in most cases by self-reflective checklists adapted from Lejuez et al. (2011).

Analysis plan

Participant demographics, screening and Session 1 assessment scores were described and compared by condition using *t*-tests, chi-squared test, or Fisher's exact tests. Between and within-group effect sizes (Cohen's *d*) were reported for PHQ-9 and BADS-SF scores from Session 1 to Session 3. Fisher's exact tests were performed to compare activities completed (Yes/No) between sessions, conditions, and conditions at each session. Correlations between screening and Session 1 to outcome change rates in depressive symptoms and activity engagement were performed using Pearson's correlation.

A series of intention-to-treat mixed effects linear models (MLMs) were performed to examine change in depression severity and engagement in positively reinforcing activities. First, an MLM was performed to predict depression severity (PHQ-9) based on condition (BA + AC or BA + MI) and session (Session 1, Session 2, Session 3). Participant-level random intercepts and slopes for Session were included in the model to account for individual heterogeneity in post stroke depression (López-Espuela et al., 2020), in both initial PHQ-9 scores and changes over time. Two exploratory models followed sequentially, adding covariates into this model: verbal episodic memory performance at screen (LMT continuous scores), and Session 1 self-reported everyday memory difficulties (EMQ-R continuous scores). This plan varied slightly from the pre-registered analysis plan, which stated that LMT scores would be included as a covariate in the primary outcome. This decision was made in order to first, identify the effects of MI on depression severity, and second, explore whether and how different types of memory affect this relationship.

This approach was mirrored for predicting engagement in positively reinforcing activities (BADS-SF): an MLM examined BADS-SF by condition and session and was then repeated twice, sequentially adding covariates for verbal episodic memory performance and self-reported everyday memory difficulties.

Assumptions of MLM were evaluated for all models. MLM was performed using the "*lme*" function from the *nlme* package (Pinheiro et al., 2025) using *RStudio* on *R*. Tukey-adjusted post-hoc tests were performed to explore interaction effects using the "*emmeans*" function from the *emmeans* package (Lenth et al., 2023).

Results

Of the 158 people completing an eligibility screen, 55 were eligible, and 45 participants were randomized, with 23 of which allocated to the BA + MI condition (Figure 1). Neither scores at Session 1, screening measures, nor demographic characteristics significantly differed between the BA + MI and BA + AC conditions (Table 1), suggesting that block-randomization was effective. See Supplemental Materials for detailed participant ethnicity breakdown.

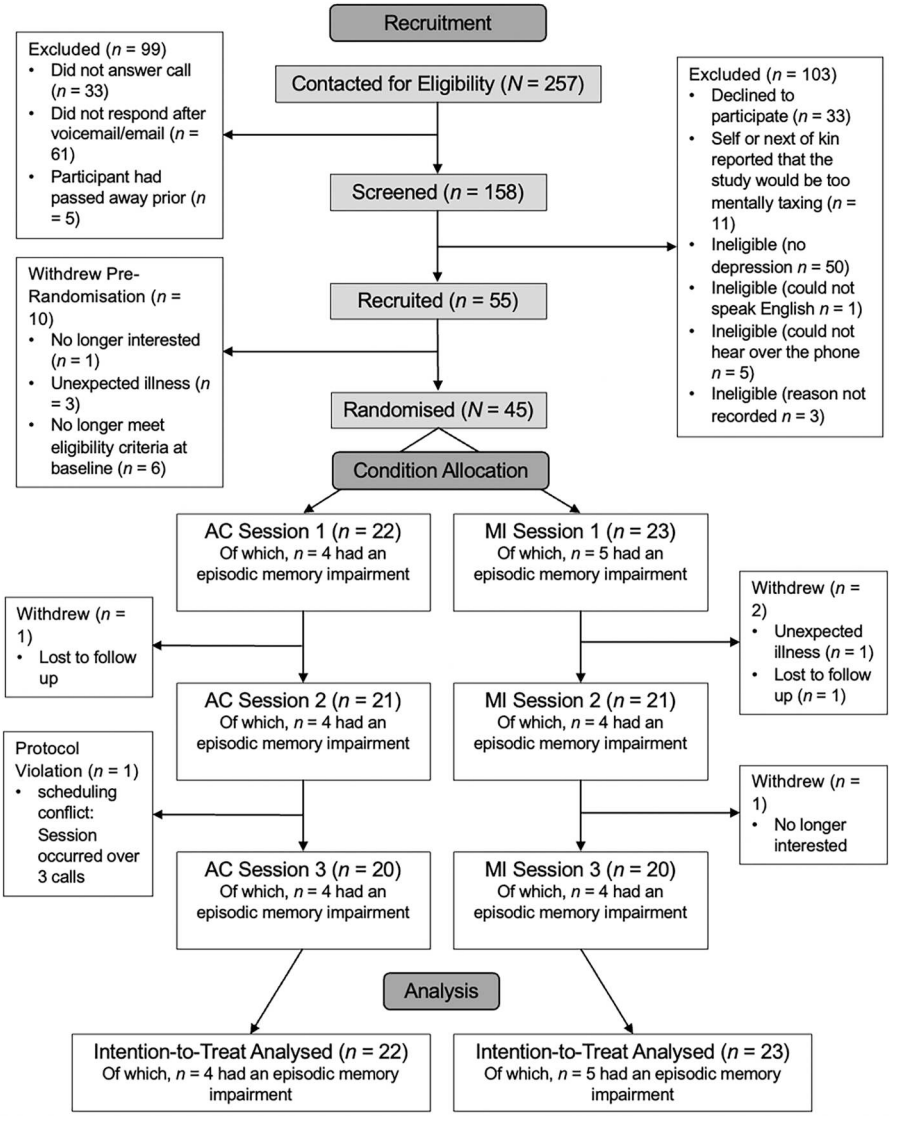

Figure 1. CONSORT flow diagram.

Note: MI: mental imagery; AC: active control, episodic memory impairment defined as performance <5th centile on Logical Memory Test I of the Wechsler Memory Scale (3rd Edition) at screen. Recruitment took place from early 2023 to late 2024.

Activities completed

The most commonly scheduled activities were gardening, reading, walking outside, and interior decorating/renovating. Less commonly scheduled activates included crocheting, singing, baking, and woodcarving (Supplemental Materials). There were no significant differences in planned activities completed between conditions at any session, or between sessions (Supplemental Materials).

Table 1. Demographic data and measures by condition.

Characteristic	Mean (*SD*) of Condition		*t* statistic (*df*)	*p* value
	BA+AC (*n* = 22)	BA+MI (*n* = 23)		
Age (years)	71.43 (11.11)	67.24 (12.29)	1.20, (42.87)	.237
Education (years)	12.43 (3.47)	13.57 (3.42)	-1.10 (42.85)	.276
Months Since Stroke	38.10 (31.59)	34.01 (30.12)	0.44 (42.63)	.659
NIHSS Score	6.91 (4.66)	7.71 (4.82)	-0.56 (40.73)	.580
LMT at Screen	39.73 (33.39)	34.04 (28.07)	0.62 (41.07)	.541
VVIQ at Screen	66.14 (9.15)	68.74 (12.56)	-0.80 (40.21)	.430
PHQ-9 at Session 1	12.23 (3.94)	12.13 (5.35)	0.07 (40.42)	.945
BADS-SF at Session 1	27.09 (9.87)	27.61 (8.98)	-0.18 (42.19)	.855
EMQ-R at Session 1	35.91 (13.48)	39.87 (13.26)	-0.99 (42.83)	.326
	Percentage of Cohort % (*n*)		Fisher's exact test	*p* value
Ischaemic Stroke	44.44 (20)	40.00 (18)		.414
Haemorrhagic Stroke	4.44 (2)	11.11 (5)		.414
Right Hemispheric	26.67 (12)	24.44 (11)		.768
Left Hemispheric	20.00 (9)	22.22 (10)		1.00
Bilateral Hemispheres	2.22 (1)	2.22 (1)		n/a
Hemisphere Undetermined	2.22 (1)	2.22 (1)		n/a
First Ever Stroke	35.55 (16)	33.33 (15)		.749
Recurrent Stroke	13.33 (6)	17.78 (8)		.749
White Ethnicity	93.75	94.11		1.00
Male Sex	54.54 (12)	65.21 (15)	χ^2 (1) = 0.18	.670

Note: SD: standard deviation; NIHSS: National Institute of Health Stroke Severity Score; LMT: logical memory test; VVIQ: vividness of visual imagery questionnaire; PHQ-9: patient health questionnaire–9; BADS-SF: behavioural activation for depression scale – short form; EMQ-R: everyday memory questionnaire – revised; n/a: not applicable, Levene's tests were non-significant for all comparisons so parametric two tailed t-tests were performed, the chi-squared test was Yates-corrected.

PHQ-9 and BADS-SF descriptives

There was a large between-condition effect size for PHQ-9 scores at Session 2 (Cohen's $d = 0.65$, 95% CI [0.01, 1.29]: Figure 2). BA + MI participants demonstrated significant within-group improvement in mood from Session 1 to Session 3 (Cohen's $d = 0.77$, 95% CI [0.13, 1.40]), but this was not observed in the BA + AC condition (d = 0.28, 95% CI [−0.34, 0.90]). Depression severity appeared to decrease at a greater rate for BA + MI participants relative to the BA + AC condition (Figure 2).

From Session 1 to Session 3 both BA + MI (Cohen's $d = -0.87$, 95% CI [−0.22, −1.52]) and BA + AC (Cohen's $d = -0.66$, 95% CI [−0.03, −1.29]) participants experienced within-group activity level improvements. There were no between-group differences in BADS-SF increases across sessions between the two conditions (Figure 2; Supplemental Materials).

Correlates of primary outcome

Details of correlations between measures are in the Supplemental Materials. In brief, across the full sample ($N = 45$) greater Session 1 depression severity correlated with activity engagement ($r = -.61$, $p < .001$), subjective memory difficulties ($r = .40$, $p < .01$) but not objective memory ($r = .08$, $p = .59$). Change in depression severity from Session 1 to Session 3 correlated only with changes

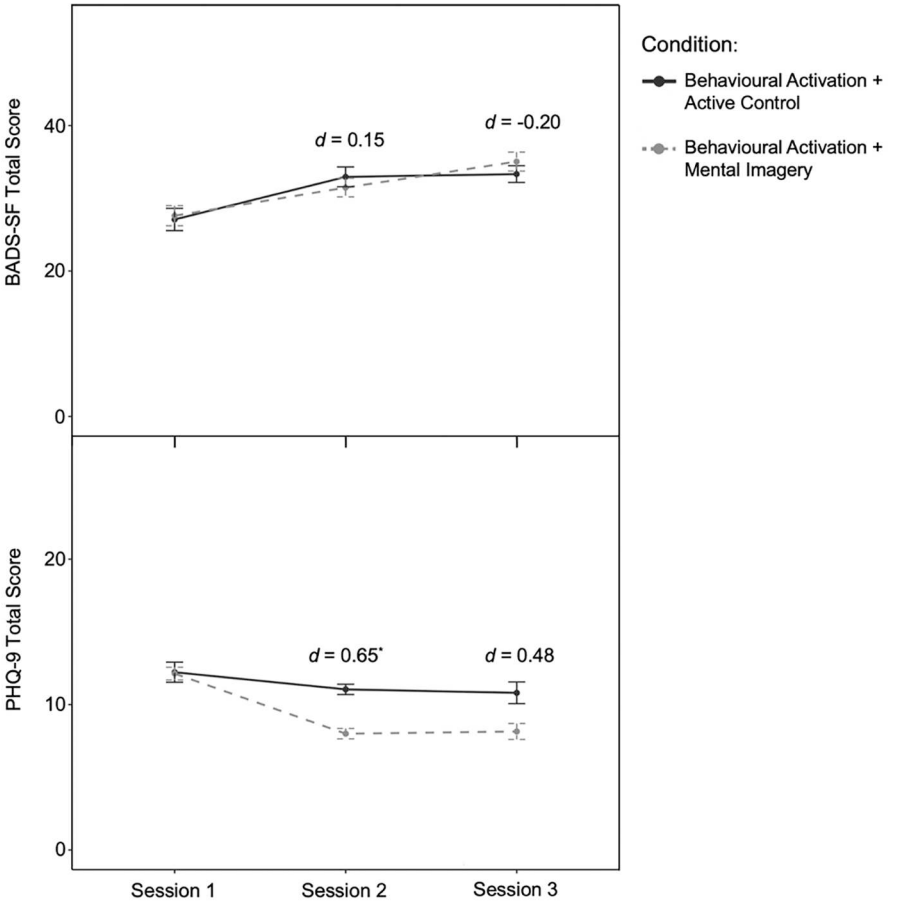

Figure 2. Mean BADS-SF and PHQ-9 scores by session and condition. Between group Cohen's d effect sizes are shown.

Note: ADS-SF: behavioural activation for depression scale – short form, PHQ-9: patient health questionnaire – 9, *Significant where 95% confidence intervals do not include zero, Error bars represent ±95% standard error.

in activity engagement ($r = -.43$, $p < .01$) and not with objective ($r = -0.27$, $p = .08$) or subjective memory ($r = -.04$, $p = .79$).

PHQ-9 model

All assumptions of MLM were satisfied for all models (Supplemental Materials). There was a significant Condition by Session interaction ($F = 3.99$, $p = .022$, VC = 20.49, SD = 4.53, ICC *adj* = .93). At Session 2, BA + MI participants showed significantly greater reductions in PHQ-9 scores compared to BA + AC participants ($t_{(79)} = -2.72$, $p = .008$: Table 2), though this between-group difference weakened at Session 3 ($t_{(79)} = -1.34$, $p = .184$). Only BA + MI participants showed significant within-group decreases in PHQ-9 scores at Session 2 ($t_{(79)} = 6.13$, $p < .001$) and Session 3 ($t_{(79)} = 3.51$, $p = .002$).

Table 2. Intention-to-treat model predicting depression severity.

	PHQ-9 ~ 1 + Condition × Session + (Session | Participant ID)			
Fixed Effect	*b* (*SE*)	*t* statistic (*df*)	95% *CI*	*p* value
Intercept	12.23 (1.00)	12.17 (79)	[10.23, 14.23]	< .001*
BA+MI Condition	-0.97 (1.41)	-0.07 (43)	[-2.93, 2.74]	.945
Session 2	-1.39 (0.61)	-2.28 (79)	[-2.61, - 0.18]	.025*
Session 3	-1.61 (0.98)	-1.64 (79)	[-3.56, 0.35]	.105
(BA+MI) × Session 2	-2.35 (0.86)	-2.72 (79)	[-4.06, -0.63]	.008*
(BA+MI) × Session 3	-1.87 (1.39)	-1.34 (79)	[-4.65, 0.91]	.184

Note: PHQ-9: patient health questionnaire-9; BA: behavioural activation; MI: mental imagery; AC: active control; ID: identification, *Significant (p <.050).

Exploratory PHQ-9 models covarying for objective and subjective memory

When controlling for performance on an objective test of verbal episodic memory (LMT) at screen, the pattern of effects remained the same (see Supplemental Materials). LMT scores themselves were not significant in this model.

When controlling for subjective self-ratings of everyday memory at Session 1 (EMQ-R), the pattern of effects remained the same (see Supplemental Materials). That is, PHQ-9 scores were significantly lower in the BA + MI condition compared to the BA + AC condition at Session 2 ($t_{(79)} = -2.72$, $p = .008$) with the difference lessening by Session 3 ($t_{(79)} = -1.33$, $p = .187$). Session 1 EMQ-R scores were significant in this model ($t_{(42)} = 3.02$, $p = .004$).

BADS-SF model

There was a significant effect of Session ($F = 11.62$, $p < .001$, VC = 77.33, $SD = 8.79$, ICC $adj = .87$). Engagement in activities increased for both the BA + MI and BA + AC condition at Session 2 ($t_{(79)} = 2.77$, $p = .007$) and at Session 3 ($t_{(79)} = 3.18$, $p = .002$), relative to Session 1. However, there was neither an effect of Condition nor a Condition by Session interaction across any sessions (Table 3).

Exploratory BADS-SF models covarying for objective and subjective memory

When controlling LMT at screen, the pattern of effects remained the same (see Supplemental Materials). LMT scores at screen themselves were not significant

Table 3. Intention-to-treat model predicting activity engagement.

	BADS-SF ~ 1 + Condition × Session + (Session | Participant ID)			
Fixed Effect	*b* (*SE*)	*t* statistic (*df*)	95% *CI*	*p* value
Intercept	27.09 (2.01)	13.48 (79)	[23.09, 31.09]	<.001*
BA+MI	0.52 (2.81)	0.18 (43)	[-5.15, 6.19]	.854
Session 2	5.83 (2.11)	2.77 (79)	[1.64, 10.03]	.007*
Session 3	6.22 (1.95)	3.18 (79)	[2.33, 10.11]	.002*
(BA+MI) × Session 2	-2.25 (2.97)	-0.76 (79)	[-8.16, 3.67]	.452
(BA+MI) × Session 3	0.95 (2.77)	0.34 (79)	[-4.56, 6.46]	.731

Note: BADS-SF: behavioural activation for depression scale-short form; BA: behavioural activation; MI: mental imagery; AC: active control; ID: identification, *Significant (p <.050).

in the model investigating activity changes. When controlling EMQ-R at Session 1, the pattern of effects also remained unchanged (see Supplemental Materials). EMQ-R scores were significant in this model ($t_{(42)} = -2.22$, $p = .032$).

Results summary

Overall, while the BA + MI and BA + AC conditions both experience increases in engagement in reinforcing activities, there were no differences between groups in terms of planned activities completed, nor in level of improvement in reinforcing activity engagement on the BADS-SF. However, only BA + MI participants demonstrated within-group mood improvements. Notably, participants in the BA + MI condition had greater improvements in mood as measured by the PHQ-9 compared to BA + AC condition, particularly at Session 2. Further, in exploratory analyses objective memory neither correlated with BADS-SF scores or PHQ-9 scores in mixed effects models. However, higher subjective memory difficulties were associated with lower PHQ-9 scores over time, and lower BADS-SF scores, in a mixed-effects model.

Discussion

In this study, we aimed to evaluate whether augmenting BA with mental imagery improves mood and activity outcomes in stroke. We hypothesized that there would be a greater reduction of depression severity and greater increases in activity levels for participants receiving Behavioural Activation augmented with mental imagery relative to an active control Behavioural Activation. There was no overall difference between the two conditions in terms of activity level improvements, supporting existing literature suggesting that standard BA is an effective tool for increasing activity engagement in those with neurological conditions with low mood (Thomas et al., 2013; 2019; Oates et al., 2020; Kusec et al., 2023c). However, participants receiving BA augmented with mental imagery demonstrated a significantly greater reduction in depression severity than those receiving standard BA with an imagery-based active control. These findings are in line with existing literature suggesting that mental imagery may increase the mood-enhancing benefits of BA (Renner et al., 2017, 2021; Pellas et al., 2022). This study provides the first tentative empirical support for this effect in stroke survivors.

There are several potential pathways as to why depression severity decreased at a greater rate in the context of activity-focused mental imagery post-stroke. One possible explanation is that mental imagery enhanced prospective memory and/or motivation to engage in positive activities (Renner et al., 2019). Though we observed an overall increase in activity engagement across all participants at each session, there was, contrary to hypothesis two, no between-condition differences in activity engagement at any session, nor in the number of self-

reported planned activities completed. This suggests that activity-focused mental imagery did not increase prospective memory or motivation to engage in activities, at least in this sample. Therefore, the observed reduction in depression severity in the mental imagery group cannot be explained solely by increased activity participation. This suggests that mental imagery may not directly affect positive reinforcement, as defined by an increase in behaviour associated with reward, at least in this brief, two-session timescale. While future studies could investigate the potential role of mental imagery for positive reinforcement over a longer timescale, the present findings indicate that mental imagery likely exerted its effects in this sample through other psychological pathways rather than merely "making someone do more."

An alternative interpretation is that visualizing the planned activities and their enjoyable components may have improved mood due to the enjoyable nature of activity-focused imagery itself (Blackwell & Holmes, 2010). This is supported by the present findings that depression severity decreased over time at a greater rate amongst the active imagery participants that engaged in activity-focused mental imagery despite approximately 25% of participants not completing their planned activity. While Behavioural Activation theory emphasizes that improved mood is a result of increased positive reinforcement (Lewinsohn, 1975), it is possible in this context that mechanisms beyond behavioural engagement – such as increased positive affect from imagery – contributed to this effect. While the prompts in the imagery condition were designed to elicit sensory simulations of the activity, rather than emotional responses, imagining oneself successfully completing an activity may be inadvertently positively emotionally laden. For example, some evidence suggests that imagining completing a task with a positive resolution can, in itself, modify cognitive biases maintaining depression (Bibi et al., 2020). It is also possible that, due in part to its enjoyable nature, mental imagery augmented the degree of reward responsiveness to planned activities, enhancing the mood effects gained relative to the control condition. Neurological conditions have been reported to result in reduced sensitivity to reward (e.g., Grippa et al., 2017; Horne & Irish, 2023) that may confer vulnerability to lesser reinforcement gained from otherwise positively reinforcing activities. The enjoyability of mental imagery, coupled with its potential to enhance reward responsiveness, may have positively reinforced repeated mental rehearsals of the planned activity as a means of improving mood.

Possibly, the greater reduction in depression severity may be driven by the increased likelihood of prospective and retrospective reflection on the positively reinforcing aspects of activity engagement. As aforementioned, positive reinforcement is a theorized mechanism underlying the mood-activity relationship in Behavioural Activation (Lewinsohn, 1975). Here, mental imagery may have enhanced mood by counteracting negative recall bias of similar activities that have previously been unsuccessful or experienced as less rewarding.

Increased negative recall bias has been linked to greater depression severity in the general population (Lemogne et al., 2006) and is a transdiagnostic cognitive marker for depression symptom severity (Duyser et al., 2020). A negative bias in prospective cognition has been demonstrated to be associated with depressed mood following acquired brain injury (Murphy et al., 2019). This suggests that individuals with post-stroke depression may be more likely to struggle to extract enjoyment, satisfaction, or a sense of mastery from activities that would typically be rewarding. Pile et al. (2021) demonstrated this effect in a depressed, non-stroke population, showing that engaging in activity-focused mental imagery increased the recall of positive-valence memories. Although the present study did not directly measure recall bias, it is conceivable that mental imagery enhanced episodic recall of positive-valence memories or previous times they have positively engaged in a similar activity (e.g., enhancing positive recall of socializing with a friend), thereby improving mood.

Finally, cognitive mechanisms through which mental imagery may have enhanced mood in the context of behavioural activation may intersect. For example, the amelioration of negative recall bias is not to say that motivation is completely unaffected by activity-focused imagery in stroke populations. Rather, imagery in this population and at this timescale may have improved anticipation of, or reflection upon, an activity's rewards, rather than simply on completing the task. Mentally pre-rehearsing an activity may provide dedicated time to reflect on its benefits, increasing conscious awareness of the emotional rewards. Mentally imagining these activities could facilitate monitoring of the emotional impact of completing the activity, including pleasant sensory and emotional enjoyment. While stroke survivors may eventually experience these benefits through standard BA, activity-focused imagery may serve to enhance and accelerate this process.

The role of memory in behavioural activation and mental imagery

Exploratory analysis revealed that subjective memory difficulties at Session 1, but not performance on a verbal episodic memory test at screen, significantly predicted depression severity. Those with higher subjectively rated memory difficulties at Session 1 consistently has greater depression severity at each timepoint and lower activity engagement across sessions. Additionally, individuals who subjectively perceived their everyday memory as poor, tended to have lower mood at Session 1. While subjective memory perceptions and objective memory performance were associated negatively – consistent with previous findings (Efklides et al., 2002) – objective memory itself was not associated with depression severity, in contrast to established findings in stroke between cognitive impairment and depressive symptomology (Hackett et al, 2005; Williams & Demeyere, 2021).

The differential associations that subjective and objective memory measures had with depression severity can be interpreted through multiple lenses. The indirect link between episodic memory and depression through everyday memory here could be explained by the subjective memory questionnaire specifically targeting those memory aspects most salient to the stroke survivor in daily life, whereas the verbal episodic memory task presents arbitrary stories not directly relevant to the individual's experiences. In other words, reduced subjective awareness of one's memory could be one mitigating factor linking memory impairments to depression severity. Another possibility is that subjective memory could be spuriously linked to depression severity in this sample because of common method variance bias (Tehseen et al., 2017), given that both are self-report measures.

Another possible explanation could be that individuals with more severe depression symptoms may report more negative perceptions of their cognitive functioning, partly due to the association between depression and increased negative recall bias (Duyser et al., 2020).

Additionally, the finding that depression severity decreased more in the mental imagery group over time, despite the overall association between subjective memory difficulties and depressive symptoms, suggests that mental imagery may be an effective adaptation for individuals with greater subjective cognitive difficulties. This aligns with research indicating that subjective cognitive difficulties are more relevant to mood in long-term stroke compared to objective cognitive difficulties (Kusec & Demeyere, 2024).

Further, objective performance on a verbal episodic memory task did not predict reinforcing activity levels. This is positive in the context of BA, suggesting that activity scheduling on its own may not be overly cognitively demanding for stroke survivors and, irrespective of condition, increases in activity levels were relatively achievable for stroke survivors. However, systematic reviews have indicated a relationship between memory and post-stroke activity (Mole & Demeyere, 2020; Stolwyk et al., 2021), in particular for visual memory. It is possible that verbal episodic memory is less relevant to activity completion compared to visual episodic memory, which may be of interest for future research.

Clinical implications

Mental imagery is an easily scalable and trainable intervention augmentation for stroke populations. Hart et al. (2020) demonstrated the mood-enhancing benefits of a single-session Behavioural Activation intervention supplemented with text reminders in a brain-injured population. However, mental imagery offers unique advantages beyond external reminders. First, mental imagery is a low-cost, accessible intervention for stroke survivors and is already used in the context of physiotherapy, for example (Laures-Gore et al., 2021; Pile et al., 2021). The present study illustrated how it can be seamlessly integrated with

Behavioural Activation into a single, deliverable intervention – ideal for services where follow-up (e.g., via activity text reminders) is infeasible. Second, while external reminders may increase activity completion (Hart et al., 2020), the results here suggest that activity-focused mental imagery may enhance the mood benefits derived from these activities. This underscores its potential as a valuable tool for maximizing mood benefits, particularly in settings with limited capacity for extended care.

This experiment could be extended to disambiguate the mechanism through which mental imagery affects activity planning. Our interpretation of the present findings assumes that mentally pre-rehearsing activities enhances positive reinforcement during and after activity completion. Explicitly measuring which positive or negative aspects of the planned activity participants recall could help determine whether any changes in negative recall bias are due to increased recall of positive-valence memories, decreased recall of negative-valence memories, or both.

Limitations

The main limitation of the study is its scope: this was a very brief intervention, with only two active sessions and a one-week follow-up, designed to specifically isolate the effect of activity-focused imagery. As a result, it is unclear whether the observed effects here would be maintained long term. Opportunity sampling likely introduced bias, which may be reflected in the disproportionate underrepresentation of people from minoritized ethnicities in the present study. Therefore, this study should be replicated in a more diverse and representative sample. This is particularly important given that Black and South Asian individuals are at a higher risk of stroke (Lekoubou et al., 2021) and are more likely to experience depression (Bailey et al., 2019). Further, an inherent limitation of mental imagery as an intervention is its inaccessibility to individuals with aphantasia (those who cannot form mental images), who may make up to 4% of the general population (Dance et al., 2022), though one study found that less than 1% of self-reported aphantasics have experienced a stroke (Dawes et al., 2020). Further, although we found objective verbal episodic memory does not relate to mood and activity changes, we did not exclusively recruit participants with very poor episodic memory abilities and therefore future research should extend this research in stroke samples with varying ranges of cognitive abilities. Additionally, while a yes/no measure of whether participants completed a specific activity was recorded, the BADS-SF only measures general participation in activities, limiting our ability to comment on the extent or quality of engagement of the selected and imagined activity in BA. A conceptual limitation is the assumption that Behavioural Activation alleviates depressive symptoms in the same way for stroke survivors and members of the general population, which requires explicit testing in further research.

Conclusion

Mental imagery is a low-cost, scalable, and accessible technique to use in conjunction with Behavioural Activation. This is the first study to provide tentative empirical support that augmenting a Behavioural Activation intervention with mental imagery can improve mood in stroke survivors. Subjective, rather than objective, memory abilities impacted on mood and activity levels in the context of the intervention. Future research should continue exploring how cognitive impairments affect depression outcomes and how to maximize the accessibility of mental health interventions to benefit stroke survivors.

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Data availability statement

Data stored on open science framework: https://osf.io/b2eup/

Writing of the code used to support these findings was facilitated by ChatGPT, which also used to enhance clarity and succinctness of language at various points within the manuscript.

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