



Effects of *Panax ginseng* and *Panax quinquefolius* on Cognitive Function: A Systematic Review

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Abstract

Ginseng has a longstanding reputation as an adaptogen, antistress agent and cognitive enhancer. We conducted a systematic review of randomised controlled studies into the cognitive effects of ginseng in non-clinical populations. The initial search captured 1802 records, of which fourteen articles fulfilled the inclusion criteria and were included in this review. The majority of the studies ($N=11$) examined the effects of standardized extracts of *Panax ginseng* (Asian ginseng), with most ($N=8$) using a standardised extract. The other three used a standardised extract of *Panax quinquefolius* (American ginseng). All but one study included acute assessment ranging from 1 h to 6 h post-administration. Four studies included a ‘chronic’ assessment ranging from 8 days to 12 weeks, three of which included ‘acute-on-chronic’ evaluations. Overall, the effects of *P. ginseng* tended to benefit accuracy of secondary memory (although there was evidence of a speed accuracy trade-off for specific doses), and to some degree attentional processes. *P. quinquefolius* had a more positive impact on attentional measures and working memory/executive functions. These effects are likely due to differences in ginsenoside profiles and other components via action on numerous systems, including neurotransmitter systems and glucocorticoid and estrogen receptors. Although there were some methodological consistencies across studies, different cognitive measures and extracts were utilised. Notably, the studies which did not specify the ginsenoside constituents of the extract used did not report cognitive benefits, emphasising the need for standardisation and characterisation.

Keywords Ginseng · Cognition · Attention · Working memory

Introduction

Ginseng refers to species of the *Panax* genus of the Araliaceae plant family. Extracts of Ginseng have been used for millennia in Traditional Chinese Medicine, with the role of ginseng in published pharmacopoeia being that of a ‘tonic’

to provide energy, and to aid convalescence in the ill and elderly (Fulder, 1990). Different species of ginseng have a longstanding reputation for their health benefits including in the context of neurocognitive function (Smith et al., 2014). The ginseng family has seventeen species, with *Panax ginseng* Meyer (Asian ginseng) and *Panax quinquefolius* L. (American ginseng) being the most commonly used in clinical trials examining the effectiveness of ginseng as a cognitive enhancer.

Ginseng Actives and Pharmacokinetics

Bioactive constituents of the *Panax* genus include the triterpene saponins known as ginsenosides. These can be classified into three groups on the basis of their chemical structure and original thin layer chromatography characterization (Chen et al., 2022). These are the panaxadiol group (Rb1, Rb2, Rb3, Rc etc.), panaxatriol group (Re, Rf, Rg1, Rg2, Rh1) and the oleanolic acid group (e.g. Ro) (Tachikawa et al., 1999). Ginsenoside quantity and quality varies

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according to various environmental factors including time of harvest (Lee et al., 2017). Of the most commonly studied extracts, G115 contains an invariant 4% ginsenosides while Cereboost™ is standardised to 11.65% ginsenosides respectively (Scholey and Kennedy 2002; Scholey et al. 2010).

Ginsenosides have been reported to exert effects on the cholinergic system, which is critically involved in attention and memory. Isolated Rb1 stimulates choline acetyltransferase activity (Salim et al., 1997) and acetylcholine release (Benishin et al., 1991). Ginsenosides Rg1 and Rb1 have also been found to elicit marked alterations in brain serotonin concentrations, which may influence mood and sleep patterns. Other targets include nerve growth factor (Chu & Zhang, 2009). Rb1 was capable of in vivo modulation of long-term potentiation, a putative analogue of memory formation (Abe et al., 1994). Other ginsenosides have also been reported to affect specific cognition-relevant mechanisms. For example, Rd influences corticosterone secretion (Hiai et al., 1983), while ginsenosides Rd and Re may increase levels of the norepinephrine, dopamine, serotonin and GABA (Chu & Zhang, 2009; Tsang et al., 1985). In rodents ginseng administration attenuated learning deficits associated with ageing (Nitta et al., 1995; Wen et al., 1995; Zhao & McDaniel, 1998) or forebrain ischemia (Nitta et al., 1995) where ginseng was also neuroprotective, rescuing hippocampal neurons. In young rodents, ginseng-related improvements may follow an inverted U dose-response. Mice administered 3, 10, 30, 100 and 300 mg/kg *Panax* ginseng (extract G115) improved performance following 10 mg/kg in an inverted-U dose-response manner. However this effect was observed for a selection of tasks only (Petkov & Mosharrof, 1987). Animal studies have observed cognitive benefits over a range of doses, ranging from 10 mg/kg to 150 mg/kg body weight (Petkov et al. 1993; Petkov and Mosharrof 1987), with higher doses within this range also appearing to impair aspects of cognitive function (Petkov & Mosharrof, 1987).

Like *P. ginseng*, *P. quinquefolius* (PQ), or American ginseng has been reported to possess a wide range of activities including effects on the central nervous system (CNS) (Bokelmann, 2022; Smith et al., 2014; Vandenhouten Eric et al., 2019). These effects may differ from those associated with *P. ginseng* as the two species differ quantitatively in the relative levels of ginsenosides. *P. quinquefolius* has a higher Rb1: total ginsenoside ratio than *P. ginseng*. Additionally in *P. quinquefolius*, ginsenosides Rb1, Re, and Rd are 3-, 6-, and 5-times more abundant, respectively, than in *P. ginseng*. As well as these differences in ginsenoside profiles, research on the behavioural effects of ginseng administration can be complicated by methodological issues. These include variations in methods of assessment in target cognitive outcomes and cognitive assessment batteries, age of trial participants (ranging from young adults to older cohorts), and dosage,

ranging from 10 s to hundreds of mg ginsenosides (Kennedy & Scholey, 2003). Although it is worth noting that these issues are not uncommon in the field of nutritional cognitive neuroscience (Scholey, 2018).

Regarding the quality of research on ginseng in general, using the 37-item CONSORT checklist, Chen et al. (Chen et al., 2022) analysed the quality of 91 randomized controlled trials (RCTs), 72 using *P. ginseng* and 19 using *P. quinquefolius*. Their conclusion was that, although historically trials have been of mixed quality, more recent trials are methodologically more robust.

We conducted a systematic review to determine if there were consistent effects of standardised extracts of ginseng on cognitive functioning. The review is distinct from recent reviews by Chen et al., (2022) which was restricted to evaluating quality of ginseng trials across all health outcomes (specifically to evaluate “the quality of the RCTs that have been conducted on American ginseng and Asian ginseng”), and a recent narrative review on biobehavioural effects of the *P. quinquefolius* species only (Bell et al., 2025). The aim of this systematic review is to evaluate the evidence on cognitive outcomes following either *P. ginseng* or *P. quinquefolius* administration either acutely or chronically. We hypothesised that the different ginsenoside composition of *P. ginseng* and *P. quinquefolius* would result in differential effects on aspects of cognitive performance.

Methods

Searches

Medline (PubMed and Web of Science), Scopus and PsycINFO were searched for randomized controlled trials until October 2022 by combining terms relating to the outcome (“cognit*”, “memory”, “attention”) and terms relating to the intervention (“ginseng”, “panax”, “quinquefolius”, “panax ginseng”, “panax quinquefolius”, “Asian ginseng”, “American ginseng”).

Where possible, search results were automatically filtered using the following limits and/or terms relating to the study design: “human studies”, “randomised control trial”, “randomized control trial”, “randomised controlled trial”, “randomized controlled trial”, “clinical trial”. In addition, further studies were examined based on examination of reference lists from relevant studies.

Eligibility Criteria

The primary focus of this review was to evaluate the effects of ginseng administration on cognitive performance. In accordance with Preferred Reporting Items for Systematic

Reviews and Meta-Analyses (PRISMA) guidelines, to limit heterogeneity between the included studies, the following inclusion criteria were used. To be considered for selection, trials had to be randomized, double-blind, placebo-controlled trials and had to report a cognitive outcome (including attention, memory, and executive function). Additionally, the cognitive outcome must have been quantifiable, which means any change could be measured as a function of intervention. Only studies involving non-clinical populations were included.

Results

Study Selection

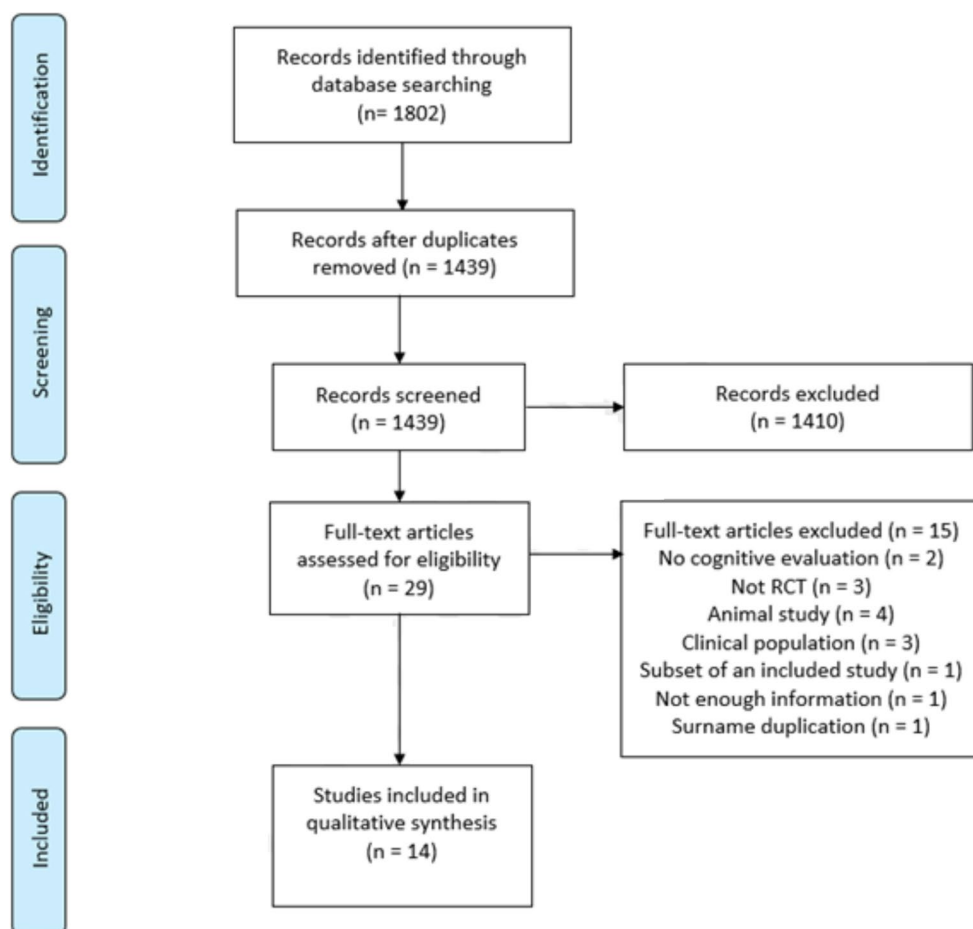
The initial search captured 1802 records. After duplicates were removed, 1439 titles and abstracts were screened for potentially relevant RCTs, following exclusion for reasons such as being an animal study, a case study, a review, not including cognitive measures, not placebo-controlled etc., the full text of 29 studies assessed for their eligibility. Fourteen articles fulfilled the inclusion criteria and were included in this review. The same search terms entered into Scopus

in October 2024 did not capture any new studies meeting the inclusion criteria. Figure 1 outlines the search process and reasons for exclusion. Of the 30 articles assessed for eligibility 15 were excluded. Of these, two articles had no cognitive measure (Baek et al., 2019; Cardinal & Engels, 2001), three were not RCTs (Neale et al., 2013; Persson et al., 2004; Tardy et al., 2021), four were animal studies (Churchill et al., 2002; Peng et al., 2021; Petkov et al., 2003; V. D. Petkov et al. 1993), three were in clinical populations (Ko et al., 2014; Lyon et al., 2001; Park et al., 2019), one was a sub-study of an included study (White et al., 2020), one had insufficient information for evaluation (Sakovics et al., 1977), one was part of an included study (White et al., 2020), one had insufficient information for evaluation (Sakovics et al., 1977), and one was listed in different bibliographies with different surnames for the same author (Ong Lai Teik et al. 2016).

We note that the reduction to 14 from 1802 records here (0.008%) is a similar percentage to the 92 from 10,610 reported in Chen et al. (2022), at 0.009%. This may be a reflection of the variable quality of studies in this area.

The remaining 15 articles (describing 14 studies) are included in the review (Bell et al. 2021; D'Angelo et al. 1986; Kennedy et al. 2001, 2002, 2004, 2007; LaSala et al.

Fig. 1 Flow diagram depicting the selection process for articles included in this review



2015; Mariage et al. 2020; Ong Lai Teik et al. 2016; Ossouk-hova et al. 2015; Reay et al. 2005; J. L. Reay et al. 2006; J. L. Reay et al. 2010; Scholey et al. 2010; A. B. Scholey & D. O. Kennedy, 2002) and summarised in Table 1. The following sections are restricted to cognitive effects of ginseng administration.

***Panax ginseng* Acute Administration**

A series of 3 acute trials published in 4 manuscripts, by Kennedy et al. (Kennedy et al., 2001, 2002, 2004) implemented a similar acute, repeated-measures, placebo-controlled, double-blind, balanced, crossover design which included at least one ginseng arm using an extract of *P. ginseng* (G115), standardized to 4% ginsenosides. Testing took place at a pre-dose baseline then at 1 h, 2.5 h, 4 h, and 6 h post-dose, with each testing day being separated by a 7-day washout period.

The studies utilized the same cognitive assessment tool - the Cognitive Drug Research (CDR) computerized assessment battery. The CDR battery comprises around 11 cognitive tasks, the outcomes of which can be combined to generate four cognitive outcome factors corresponding to 'quality of memory', 'speed of memory' (how quickly information is retrieved in recognition tasks), 'speed of attention', and 'accuracy of attention'. Quality of Memory is further broken down into the two further factors of 'working memory' (where information is held in consciousness and operated on 'online') and 'secondary memory' (where information is learned and later retrieved).

The first of these studies investigated the acute changes in cognitive performance and mood following single doses of G115 in 20 healthy young (mean age 21 years) volunteers (Kennedy et al., 2001). Participants ingested 200 mg, 400 mg, and 600 mg of ginseng, on separate days. With regards to the four cognitive factors, compared with placebo, 200 mg of G115 led to a significant slowing in the 'speed of memory' 4 h post-dose and also significant slowing in 'speed of attention' 4 h and 6 h post-dose. The same 200 mg dose led to improvements in the 'accuracy of attention' 6 h post-dose. The 400 mg dose led to significant improvements in 'quality of memory' at 1 h, 2.5 h, 4 h, and 6 h post-dose, in comparison to placebo. The 600 mg dose led to significant improvements, as compared to placebo, in 'quality of memory' at 2.5 h, however, the same dose led to a significant slowing in the 'speed of attention' at 4 h and 6 h. For the 'Quality of Memory' factors, there was no significant effects of any dose, at any post-dose testing session, in comparison to placebo, on 'working memory'. The 200 mg dose led to significant improvements in 'secondary memory' at 4 h post-dose. Similarly, 400 mg and 600 mg led to significant improvements in 'secondary memory' performance at 1 h,

2.5 h, 4 h and 6 h (400 mg only). Turning to the individual tasks that load the 'secondary outcome factors' the results revealed no effect of any dose on the tasks contributing to 'working memory'. However, when examining the individual tasks that load 'secondary memory' (i.e. Immediate Word Recall, Delayed Word Recall, Delayed Word Recognition, Delayed Picture Recognition), the results revealed that all doses improved performance of the four individual tasks, as compared to placebo. The effect was most pronounced for the 'Immediate Word Recall' task, with a significantly greater number of words recalled, as compared to placebo, at 1 h, 2.5 h, 4 h, and 6 h post-dose following the 400 mg (G115) dose. Similarly, 600 mg was associated with a significantly greater number of recalled words at 1 h, 2.5 h and 6 h post-dose. There was also a single significant improvement 4 h post-dose following 200 mg. A consistent pattern also emerged on the 'Delayed Word Recognition' task with significant improvements revealed following both 400 mg and 600 mg (G115) at 1 h (400 mg only), 2.5 h and 6 h post-dose. In the 'Delayed Picture Recognition' 200 mg and 400 mg led to significantly improved performance at 1 h post-dose. Whereas a greater number of words were recalled in the 'Delayed Word Recall' task following 400 mg at 2.5 h post-dose. When the individual tasks (i.e. simple reaction time, choice reaction time and digit vigilance reaction time) that load the 'Speed of Attention' factor are examined in more detail it is apparent that 400 mg and 600 mg (G115) led to a significant slowing in 'simple reaction time' 4 h (600 mg only) and 6 h post-dose, while 200 mg led to significant slowing of 'choice reaction time' at 1 h, 4 h and 6 h post-dose. Additionally, both, 200 mg and 600 mg led to significant slowing in 'Digit Vigilance' at 4 h and 6 h post-dose. Inspection of the individual tasks that load the "Accuracy of Attention" factor, results revealed that both 200 mg and 600 mg led to significantly poorer accuracy in performing 'digit vigilance' at 2.5 h post-dose testing session. In contrast, 400 mg resulted in improved accuracy of performing the same task at 1 h and 4 h post-dose, as compared to placebo. With regards to subjective self-reported mood, both 200 mg and 400 mg (G115) were associated with significant reductions in 'alertness' 6 h post-dose. The second study, similarly, investigated the mood and cognitive effects of single doses of *P. ginseng*, *ginkgo biloba*, and a ginkgo-ginseng combination in 20 (mean age 21.2 years) young, healthy volunteers (Kennedy et al., 2002). Participants received four treatments: placebo, 360 mg of Ginkgo, 400 mg ginseng, and 960 mg of the combination on separate testing days separated by a 7 day washout period. There were significant improvements in 'quality of memory' for all three active doses, in comparison to placebo. These improvements were restricted to single post-dose time point improvement at 4 h and 6 h following ginseng and ginkgo

Table 1 Overview of the included placebo-controlled clinical studies into cognitive effects of ginseng

A. Panax ginseng					
First author and reference	Design	Population (mean age)	Dose(s) Extract [% ginsenosides]	Cognitive measures	Results
D'Angelo et al. (1986)	Rd, PC, DB, P; 12 wk	32 male student volunteers, aged 20–24 years (21.9±1.6)	200 mg <i>G115</i> [4%]	Tapping test, simple reaction time (auditory and visual), choice reaction time, cancellation test, digit symbol substitution test, mental arithmetic, logical deduction	<i>Mental Arithmetic</i> ↑
Kennedy et al. (2001)	Rd, PC, DB, X; Acute (1, 2.5, 4, 6 h post-dose); 7-day washout	20 student volunteers aged 21.3 years (range 20–27) (14 F, 6 M)	200 mg 400 mg 600 mg <i>G115</i> [4%]	CDR [word presentation, immediate word recall, picture presentation, simple reaction time, digit vigilance, choice reaction time, spatial working memory, numeric working memory, delayed word recall, word recognition and picture recognition] with factors including <i>working memory, secondary memory, speed of memory, speed of attention, accuracy of attention</i>	<i>Quality of Memory</i> ↑ 1 h, 2.5 h, 4 h, 6-h 400 mg ↑ 2.5 h 600 mg <i>Accuracy of Attention</i> ↑ 6-h 200 mg <i>Speed of Memory</i> ↓ 4-h 200 mg <i>Speed of Attention</i> ↓ 4-h, 6-h 200 mg
Kennedy et al. (2002)	Rd, PC, DB, X; Acute (1, 2.5, 4, 6 h post-dose); 7-day washout	20 student volunteers (15 F, M = 21.2±3.9 years)	400 mg <i>G115</i> [4%]	CDR [word presentation, immediate word recall, picture presentation, simple reaction time, digit vigilance task, choice reaction time, spatial memory, numeric working memory, delayed word recall, delayed word recognition, delayed picture recognition] with factors including <i>secondary memory, working memory, speed of attention, accuracy of attention, speed of memory, quality of memory</i> , Serial Subtraction tasks	<i>Quality of Memory</i> ↑ 4 h 400 mg <i>Secondary Memory</i> ↑ 4 h, 6 h 400 mg <i>Speed of Memory</i> ↓ 4 h 400 mg <i>Accuracy of Attention</i> ↑ 2.5 h 400 mg <i>Serial 7s</i> ↑ 4 h 400 mg
Scholey et al. (2002)	Rd, PC, DB, X; Acute (1, 2.5, 4, 6 h post-dose); 7-day washout.	20 student volunteers (14 F, 6 M) (21.3±2.64 years)	200 mg 400 mg 600 mg <i>G115</i> [4%]	Serial 7 s and Serial 3 s Subtraction tasks	<i>Serial 7s responses</i> ↓ 1 h, 2.5 h, 6 h 200 mg <i>Serial 7s accuracy</i> ↓ 4 h, 6 h 400 mg ↓ 4 h 200 mg
Kennedy et al. (2004)	Rd, PC, DB, X; Acute (1, 2.5, 4, 6 h post-dose); 7-day washout	28 student volunteers (19 f, M = 21.4 y, SEM 0.77) Baseline, post (1, 2.5, 4, and 6 h)	400 mg <i>G115</i> [4%]	Sentence verification, serial 3 s and serial 7 s subtraction task, Cognitive Drug Research Battery [immediate word recall, simple reaction time, digit vigilance, choice reaction time, spatial memory reaction time, logical reasoning reaction time, numeric working memory, delayed word recall, word recognition, picture recognition] with factors including <i>speed of attention, speed of memory, accuracy of attention, quality of memory, secondary memory, working memory</i>	<i>Speed of memory</i> ↓ 1 h, 2.5 h, 6 h 200 mg Sentence Verification ↑ 2.5 h 400 mg ↑ Serial 7s ↑ Word Recognition
Reay et al. (2005)	Rd, PC, DB, X; Acute 1 h post dose (then 6×10 min cycles of CDB) 7-day washout.	30 student volunteers (16 f, M = 22.6±5.46 years)	100 mg 200 mg 400 mg <i>G115</i> [4%]	Cognitive Demand Battery [Serial 3 s, serial 7 s, RVIP]	<i>Serial 7s</i> ↑ #responses cycle 1, 2, 3, 4 & 6 h 200 mg
Reay et al. (2006)	Rd, PC, DB, X; Acute 1 h post dose (then 6×10 min cycles of CDB) 7-day washout.	27 student volunteers (10 f, M = 21.89±4.64 years)	200 mg <i>G115</i> [4%]	Cognitive Demand Battery [Serial 3 s, serial 7 s, RVIP]	<i>Serial 3s</i> ↑ #responses cycle 3, 4 & 6 200 mg <i>RVIP</i> ↑ accuracy cycle 6 200 mg

Table 1 (continued)

Kennedy et al. (2007)	Rd, PC, DB, X; Acute 3 h on days 1, 29, and 57 & chronic (29 & 57 day) 4-week washout	18 student volunteers (13 F, M = 38.31±10.3 years)	200 mg <i>unspecified</i>	Corsi Blocks, 3-back, Alphabet Working Memory. CDR [immediate word recall, picture presentation, simple reaction time, digit vigilance, choice reaction time, spatial working memory, numeric working memory, delayed word recall, delayed word recognition] with factors including <i>secondary memory</i> , <i>working memory</i> , <i>speed of memory</i> , <i>speed of attention</i> , <i>quality of attention</i>	<i>3-back RT</i> ↑acute-on-chronic day 29; chronic day 57 <i>Corsi Block span</i> ↑chronic day 57
Reay et al. (2010)	Rd, PC, DB, X; Acute, chronic, acute-on-chronic days 1 & 8 (1, 2.5, 4 h) of 3 treatment periods 6-day washout.	30 adult volunteers (15 F, M = 22.87±4.01 years)	200 mg 400 mg <i>G115</i> [4%]	Corsi Blocks, N-back task, Random Number generator task	<i>3-back RT</i> ↓acute 1 h, 2.5 h, 4 h 200 mg ↑acute 2.5 h 400 mg ↑acute-on-chronic 2.5 h 400 mg day 8 ↓acute-on-chronic 1 h, 2.5 h 200 mg <i>3-back acc</i> ↑Acute-on-chronic 1 h, 2.5 h, 4 h 400 mg; day 8 ↓ Acute-on-chronic 4 h 200 mg; day 8
LaSala et al. (2015)	Rd, PC, DB, P; Acute Baseline, post (1 h)	30 healthy volunteers (<i>N</i> =10/group), aged 23–42 years	1200 mg <i>NUTRA™</i> 3%	Reaction time, Divided attention	No significant effects
Ong Lai Teiket al. (2016)	Rd, PC, DB, X; Baseline, post (1 h on days 1, 3, and 5) 48-h washout.	24 undergraduate volunteers (28 f, M = 20.2±2.4 years).	500 mg 1000 mg GNC Herbal Plus [3%]	Psychology Experiment Building Language Test Battery [visual search, psychomotor vigilance task, Stroop task, Bechara’s gambling task, Berg’s card sorting test, Tower of London]	No significant effects
Mariage et al. (2020)	Rd, PC, DB, X; Baseline, 6–8 h post (day 1), days 5 and 12 12/14 day washout (both specified in paper).	50 healthy volunteers with elevated stress, (mixed gender but Ns not specified, M = 37.46±8.016 years).	HRG80 [418 mg, 7.58% x2 daily] Arkapharma standard ginseng preparation (PGS) [384 mg, 3.37% x 2 daily]	d2 Attention Test (Letter Cancellation) [attention, concentration, visual-scanning speed] Memory Test (MT, Computerized Memory Flow Level 2) [learning. memory, attention]	<i>d2</i> ↑ accuracy of processing day 1 (acute), day 5, day 12 from HRG80 <i>MT</i> ↑ accuracy day 5, day 12 from HRG80 and PGS)
B. Panax quinquefolius					
First author and reference	Design	Population(mean age)	Dose(s) Extract [% ginsenosides]	Cognitive measures	Results

Table 1 (continued)

Scholey et al. (2010)	Rd, PC, DB, X; Acute (1, 3, 6 h post-dose); 7-day washout	Young adults (16 M, 16 F) Age=25.2±4.97	100 mg, 200 mg, 400 mg (single doses) <i>Cereboost</i> [11.65%]	COMPASS [word presentation, immediate word recall, picture presentation, face presentation, simple reaction time, choice reaction time, four choice reaction time, Stroop colour-word task, numeric working memory, alphabet working memory, corsi blocks, N-back, delayed word recall, delayed word recognition, delayed picture recognition, delayed face recognition, serial 7 s subtraction task, serial 3 s subtraction task, rapid visual information processing]	<i>Choice reaction time accuracy</i> ↑ 1-h, 3-h, 6-h 100 mg ↑ 6-h 200 mg ↑ 1-h 400 mg <i>Corsi blocks</i> ↑ 1-h, 3-h, 6-h 100 mg ↑ 1-h, 3-h, 6-h 200 mg ↑ 1-h, 3-h, 6-h 400 mg <i>Numeric Working Memory Speed</i> ↑ 1-h, 3-h, 6-h 200 mg <i>Alphabetic Working Memory speed</i> ↑ 1-h, 3-h, 6-h 100 mg ↑ 1-h, 3-h, 6-h 400 mg <i>Immediate Word Recall</i> ↑ 1-h, 3-h, 6-h 200 mg <i>Working Memory Factor</i> ↑ 3-h <i>Spatial Working Memory</i> ↑ 3-h
Ossoukhova et al. (2015)	Rd, PC, DB, X; Acute 1, 3, 6 h post-dose; 7-day washout	Middle-aged adults (32 F, 22 M) Age=51.63±6.47	200 mg (single dose) <i>Cereboost</i> [11.65%]	COMPASS [alphabetic working memory, Serial 7 s, rapid visual information processing, corsi blocks] CDR [word presentation, immediate word recall, picture presentation, simple reaction time, digit vigilance, choice reaction time, spatial working memory, numeric working memory, delayed word recall, word recognition and picture recognition] with factors including <i>working memory, secondary memory, speed of memory, speed of attention, accuracy of attention</i>	<i>Modified ANT</i> ↑ accuracy at 4-h, 6-h ↑ accuracy incongruent ↑ RT at 2-h <i>RVIP</i> ↑ accuracy <i>ANT</i> ↑ accuracy <i>Modified ANT</i> ↑ Accuracy 2-h, 4-h, 6-h ↑ RT 2-h, 4-h, 6-h
Bell et al. (2021)	R, PC, DB, P; <i>Acute</i> (2, 4, 6 h post-dose) <i>Chronic</i> (2 weeks) <i>Acute-on-chronic</i> (2, 4, 6 h post-dose on day 14)	Young adults (15 M, 44 F) Age 20.6±2.4 (Cereboost), 20.5±2.7 (Placebo)	200 mg (daily) <i>Cereboost</i> [11.65%]	Computerised test battery assessing attention; working memory; executive function; secondary memory	

Key. *Rnd.* randomized, *PC* placebo-controlled, *DB* double-blind, *X* crossover, *P* parallel, *M* male, *F* female, *COMPASS* computerized mental performance assessment, *CDR* Cognitive Drug Research, *ANT* Attention Network Task, *RVIP* Rapid Visual Information Processing Task, *PANAS-X* Positive and Negative Affect Schedule - expanded. ↑ improved

treatments respectively. However, following the combination treatment performance was significantly improved at 1 h, 2.5 h and 4 h post-dose. When ‘quality of memory’ is broken down into its component parts: ‘working memory’ and ‘secondary memory’, the results revealed that all three active treatments improved ‘secondary memory’ but had no effect on ‘working memory’. Improvements were reported, in ‘secondary memory’; following ginkgo at 1 h and 6 h post-dose; following ginseng at 4 h and 6 h post-dose; and following the combination at 1 h and 2.5 h post-dose. Through inspection of the individual tasks that load ‘secondary memory’ the results revealed that it is the performance on the Immediate and Delayed Word Recall tasks that was improved by all three treatments. Results also

revealed ‘speed of memory’ was significantly faster, following ginseng treatment, as compared to placebo, at the 4 h post-dose. Inspection of the individual tasks that load ‘speed of memory’, results revealed significant faster performance, following the ginseng treatment, as compared to placebo, on spatial memory performance and word recognition performance at 2.5 h and 4 h post-dose (word recognition only). A third study, utilizing the same methodology, compared the effects of guaraná with 200 mg *P. ginseng* (Kennedy et al., 2004). Following 200 mg of *P. ginseng* (G115), reaction times (digit vigilance task) were significantly faster at 6 h and performance was faster on the numeric working memory task at 2.5 h, 4 h and 6 h post-dose. Another publication focused on Serial Subtraction performance from the

aforementioned studies. Specifically, it reported the results of three separate placebo-controlled, double blind balanced crossover trials investigating the effect of *Ginkgo biloba*, *P. ginseng* and their combination on the performance of Serial Three and Serial Seven subtraction tasks (Scholey and Kennedy 2002). Twenty healthy young volunteers participated in each study. Participants were assessed at a pre-dose baseline and then at 1 h, 2.5 h, 4 h and 6 h post-dose (It should be noted that the subtraction tasks were part of the larger, 30–40 min CDR assessment and were the final tasks in the battery). 200 mg of *P. ginseng* led to a significantly slowing in the performance of the Serial Sevens task at 1 h, 2.5 h and 6 h post-dose. However, at the 4 h post-dose 200 mg was associated with a significant improvement in accuracy. Similarly, 400 mg of *P. ginseng* was associated with significant improvements in accuracy of performing the Serial Sevens task, as compared to placebo, at 4 h and 6 h post-dose. Cognitive effects of *P. Ginseng* on a deliberately demanding cognitive battery, coupled with reduced capillary blood glucose were examined by Reay et al. (Reay et al., 2005). Young adult participants were administered placebo, 200 mg and 400 mg *P. ginseng* (G115) 60 min prior to completing six 10-min cycles of a Cognitive Demand Battery comprising Serial Threes, Serial Sevens, a Rapid Visual Information Processing task (RVIP) and self-rated mental fatigue. The 200 mg treatment was associated with better performance of Serial Sevens at all but the 5th cycle of the battery and reduced mental fatigue at all but the first cycle. There was also a reduction in capillary blood glucose suggesting that the effects may be modulated by processes involving cellular glucose uptake or disposal. It is notable that a follow-up study did not find that the effect was further enhanced by co-administration of glucose with G115 (Reay et al. 2006). In this latter study the effects on mental fatigue were reproduced (though restricted to the fifth and sixth cycle of the demand battery). The ginseng treatment was also associated with better Serial Threes performance during the third, fourth, and final cycle and improved RVIP performance (reduced false alarm errors) during the final cycle.

Two further studies included acute evaluation following *P. Ginseng* administration (LaSala et al. 2015; Ong Lai Teik et al. 2016) and failed to observe any effects of ginseng on cognitive performance. LaSala et al. tested reaction time and divided attention using the STISIM3[®] Driving Simulator in a sample of 30 participants (10 per arm), one hour post administration of ginseng (1200 mg), Ginkgo (240 mg), or placebo. No significant effect of either ginseng or Ginkgo were observed on driving performance (LaSala et al., 2015). Ong Lai Teik et al. also failed to observe effects of ginsenosides on cognition at 1h after consumption in a sample of 48 undergraduates at doses of *Panax ginseng* (500 mg and 1000 mg). Performance was assessed using the Psychology

Experiment Building Language test battery. Changes in cardiovascular reactivity were also examined. While there were no effects on cognitive function performance, it was found that high dose of ginseng significantly increased diastolic and heart rate readings compared to placebo after visual search and vigilance tasks.

***Panax ginseng* Chronic Administration**

There are fewer behavioural studies addressing the potential cognition enhancing effects of longer-term administration of ginseng in healthy humans. An early study by D'Angelo included administration of 200 mg *P. ginseng* on driving-related behaviour in 32 healthy males for 12 weeks. Ginseng was associated with a significant improvement in Mental Arithmetic performance. Another ($N=16$) study reported positive effects of 8 weeks *P. ginseng* on working memory performance coupled with reduced self-rated calmness (Kennedy et al., 2007). One further study examined the effects of G115 on cognitive function acutely and after 8 days (J.L. Reay et al. 2010). Using a placebo-controlled, double blind crossover design 30 young adults (mean age=23 years) were tested on the first and eighth day 1 h, 2.5 h and 4 h following placebo, 200 mg and 400 mg G115. On day one (acute effects), both active treatments were associated with improved calmness at 2.5 and 4 h but no significant effects were observed at day eight.

A more recent study evaluated the efficacy of both single and repeated administration of 418 mg hydroponically cultivated red *P. ginseng* root preparation (HRG80) on cognitive performance in adults with mean age 37 (Mariage et al., 2020). Attention (assessed using d2 test) and memory were assessed both acutely and following 5 and 12 day administration. Acute assessment took place at 6–8 h following consumption. Participants ($N=50$) also received 384 mg of a traditionally harvested six-year-old white *P. ginseng* standard preparation (PGS) as a comparator, and placebo according to a balanced crossover design. For attentional performance, HRG80 was significantly superior compared with both PGS and placebo after single and repeated administrations at 5 and 12 days. There were no acute effects on memory but, compared with placebo, both ginseng preparations were associated with better performance on days 5 and 12. It should be noted that the primary outcome listed on the clinical trials registry is self-reported stress rather than the cognitive outcomes which are the focus of this review.

Panax quinquefolius

To date three RCTs, reported across four publications, have examined the potential for *P. quinquefolius* to affect cognitive performance and mood (Bell et al., 2021; Ossoukhova

et al., 2015; Scholey et al., 2010; White et al., 2020). All have evaluated the effects of the proprietary extract Cereboost®. The extract is produced from *P. quinquefolius* under conditions which standardize the overall ginsenoside composition to 10–12%, and two well characterized neuroactive ginsenosides Rg1 and Rb1 to 0.1–0.4% and 4–7% respectively (Smith et al., 2014). The ratio between the concentration of Rb1 and Rg1 in Cereboost® is approximately two orders of magnitude, exceeding the tenfold difference which has been suggested as sufficient for an inhibitory effect to the CNS (Chen et al., 2008).

The first RCT to systematically evaluate the potential cognitive and mood effects of *P. quinquefolius* reported that Cereboost® administration was associated with significant dose- and time-specific improvements in cognitive function (Scholey et al., 2010). In this study 32 healthy adults received 100, 200 and 400 mg Cereboost® and a matching placebo on separate visits and undertook a comprehensive computerized battery of cognitive tests at 1, 3, and 6 h. A number of Working Memory tasks were significantly improved by Cereboost®. Corsi Block span (a measure of spatial working memory) was improved by all doses at all time points. Alphabetic Working Memory was improved at all time points by 100 and 400 mg Cereboost® (but not 200 mg). Numeric Working Memory speed was improved at all time points by 200 mg only. Choice Reaction Time Accuracy was improved at all time points by 100mg and at 1 h by 400 mg and at 6 h by 200 mg. The only affected mood item was calmness which was improved at 3 h and 6 h by 100 mg Cereboost®.

These effects were further explored in an RCT focusing on Working Memory effects this time in a middle-aged group (Ossoukhova et al., 2015). This study evaluated the effects of 200 mg Cereboost® on Working Memory (the primary variable). Fifty-two participants (mean age 52 years) were tested at baseline, then at 1 h, 3 h and 6 h following placebo and 200 mg Cereboost®. Again, working memory was differentially improved, this time at 3 h post administration by the active treatment. This effect was evident in both a Working Memory ‘factor’ combining two working memory tasks – spatial working memory and numerical working memory. The effect appeared to be driven by similar 3 h improvements in performance of a Spatial Working Memory task which contributes to the Working Memory factor. This study also included a neuroimaging component which is described in the Discussion section.

A more recent article investigated acute, chronic and acute-on-chronic benefits of 200 mg Cereboost® on mood and cognition in young adults (Bell et al., 2021). Improvements were observed for a measure of attention during the 6-hour postprandial period. Specifically, accuracy was better for the Cereboost® treatment group compared with

placebo group on cognitively demanding, incongruent trials during an Attention Network Task (ANT). There was also some evidence of a benefit to ANT reaction time. Following two weeks daily supplementation, the benefits to ANT performance were maintained. In addition, working memory benefits were observed on a rapid visual information processing task (RVIP), through a reduction in commission errors (false positives) in the Cereboost® group compared to placebo. Mood benefits also became apparent after continued daily supplementation, with participants in the Cereboost® group self-reporting lower levels of mental fatigue and increased self-assurance compared to the placebo group. Interestingly, the acute-on-chronic investigation revealed a strengthening of the acute benefits observed at the beginning of the study, with ANT benefits observed at a greater number of postprandial time points than observed initially, while additional benefits also emerged for switching ability on a switching task (TST) and working memory accuracy on a Corsi Blocks task. The changes to working memory and attention observed by Bell et al. are entirely consistent with previous investigations of Cereboost® in similar age groups (e.g., Ossoukhova et al., 2015; Scholey et al., 2010), further evidencing the cognitive benefits of American ginseng.

Discussion

The majority of the studies examined the effects of standardized extracts of *P. ginseng* (D’Angelo et al. 1986; Kennedy et al. 2001, 2002, 2004, 2007; LaSala et al. 2015; Ong Lai Teik et al. 2016; Reay et al. 2005; J. L. Reay et al. 2006; J. L. Reay et al. 2010; A. B. Scholey & D. O. Kennedy, 2002), with most ($N=8$) using the standardised extract G115. The other three used a standardised extract of *P. quinquefolius* (Bell et al., 2021; Ossoukhova et al., 2015; Scholey et al., 2010). All but one study (D’Angelo et al., 1986) included acute assessment with testing times ranging from 1 h to 6 h post-administration. This timing coincides with detectable levels of ginsenosides in humans within 2 h, and t_{max} typically occurring at 3 to 5 h post-administration (Choi et al., 2020). Five studies included a ‘chronic’ assessment ranging from 5 days to 12 weeks, of these three included ‘acute-on-chronic’ assessments.

P. ginseng

Overall, *P. ginseng* administration tended to benefit accuracy of secondary memory as measured by higher accuracy on individual tasks of (e.g.) word memory and composite measures aggregating accuracy of recall and recognition. In fact, there was evidence of a speed accuracy trade-off, with

slower retrieval times associated with ginseng for specific doses in some studies.

It appears to be the case that *P. ginseng* or its constituents are capable of producing tangible acute cognitive enhancing effects and that for *P. ginseng* a dose equivalent to 200 mg or (particularly) 400 mg of a 4% ginsenoside extract may be the optimal dose for young healthy adults when administered acutely prior to a cognitive test. While there are also benefits from other doses, these also less consistently beneficial and, in the case of the 600 mg dose, have reported costs in some studies (see Table 1). Conversely, *P. quinquefolius* appears to differentially benefit working memory and attentional/executive processes, suggesting that the different complement of ginsenosides may result in functionally different effects on cognition (with the caveat that there are relatively far fewer studies on the latter).

Few conclusive interpretations can be made from the chronic studies of *P. ginseng* as they have investigated different cohorts (i.e. healthy young and middle aged), administered different ginseng extracts (e.g. G115, Gerimax or HRG80) and doses (200 mg and 400 mg), for different durations (5 days to 12 weeks) and implemented various assessment tools designed for different aspects/domains of cognitive functioning. Further research is required to examine the chronic use of ginseng on neurocognitive outcome measures.

In addition to the cognitive RCTs included in this review, there are other human studies which may shed light on underlying mechanisms of action. One study has investigated electroencephalograph (EEG) effects of single doses of both *Ginkgo biloba* (360 mg GK501) and *P. ginseng* (200 mg G115) in 15 (mean age 26.6) healthy young volunteers (Kennedy et al., 2003). Utilising a double-blind, placebo-controlled, balanced, crossover design, participants were assessed on three separate occasions 4 h post-dose. Results revealed that ginseng led to a significant shortening of the P300 latency component of auditory evoked potential, reflecting faster stimulus evaluation. Additionally, both ginseng and ginkgo led to significant reductions in the frontal ‘eyes closed’ theta and beta activity, with additional reductions in the alpha waveband for ginseng which may reflect better cognitive functioning (Barry et al., 2007).

In a study available as a conference abstract, Sünram-Lea et al. (2004) assessed the acute mood and cognitive effects of single doses of *Panax ginseng* (400 mg) in 30 healthy, young (mean age 20 years) volunteers (Sünram-Lea et al., 2004). Utilising a placebo controlled, double blind, balanced, crossover design participants received either 400 mg *Panax ginseng* (G115) or placebo. They completed the CDR computerised battery and Bond Lader visual analogue mood scale at a pre-dose baseline and then at 90 min post-dose. Results revealed that 400 mg ginseng, as compared to

placebo, led to significant improvements in ‘speed of attention’ 90 min post-dose. When considering the individual tasks that load the ‘speed of attention’ (i.e. simple reaction time, choice reaction time, digit vigilance reaction time) it was revealed that ginseng led to significant speeded choice reaction times at 90 min post-dose, as compared to placebo.

The acute studies identified both positive, and to a lesser extent, negative, cognitive effects of single doses of *P. ginseng* (standardised extract G115) in healthy young adults. The most consistent finding is of improved secondary memory performance following G115. Whilst these memory effects appear to be robust, particularly following a single dose of 400 mg, in one instance both lower (200 mg) and higher (600 mg) doses led to significantly slower performance of attentional tasks (Kennedy et al., 2001). Similarly, in the same cohort, whilst 400 mg improved accuracy of performing a serial subtraction task, 200 mg led to modest, but significant, reductions in the speed of performing the same task (Scholey and Kennedy 2002). These findings contrast with those from Kennedy, Haskell et al. (2004) and from Sünram-Lea, Birchall et al. (2004). Specifically, Kennedy, Haskell et al. 2004 found that 200 mg improved speed of information retrieval, attention and arithmetical performance, and significantly shortened latency of the P300 component of auditory evoked potentials (Kennedy et al., 2003). Sünram-Lea, Birchall et al. (2004) reported faster responses on an attentional task 90 min after ingestion of 400 mg G11. Additionally, a recent report has found better performance on a deliberately demanding cognitive battery coupled with reduced capillary blood glucose (J. L. Reay et al. 2006).

P. quinquefolius

Compared with *P. ginseng*, totality of evidence on *P. quinquefolius* is smaller. Overall, findings from 3 RCT suggest a positive impact of *P. quinquefolius* on attentional measures and executive function. These effects are likely due to differences in ginsenoside profiles and other components via action on numerous systems, including neurotransmitter systems and glucocorticoid and estrogen receptors (Shi et al., 2019).

One study (involving a subset of participants from Ossoukhova et al.) examined the effects of *P. quinquefolius* on brain activation using Steady State Visually Evoked Potential (SSVEP) neuroimaging (White et al., 2020). During the retrieval phase of a spatial working memory task, *P. quinquefolius* was associated with significantly reduced prefrontal SSVEP latency. The authors interpret this pattern as reflecting increased recruitment of prefrontal brain regions during working memory processing. This provides preliminary evidence that *P. quinquefolius* may allow the

use of more neural resources during working memory task performance.

The studies included in this review met our pre-defined inclusion criteria. It is worth noting, however, that verall, there is a considerable body of evidence supporting cognitive benefits from both *P. ginseng* and *P. quinquefolius* as detailed in this review. Nevertheless, achieving a robust behavioural profile of cognitive effects of ginseng is complicated because of variations in methods of assessment, participant age and dosage used. In conclusion, cognitive facilitating effects of ginseng have been observed both acutely and after single dose administration, providing sufficient support to further explore the potential of this ingredient within a food product as a nutritional solution for acute mental performance.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Human Ethics and Consent to Participate Not applicable.

Competing Interests Evelina De Longis and Julie Hudry are employed by the Société des Produits Nestlé.

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References

- Abe, K., Cho, S. I., Kitagawa, I., Nishiyama, N., & Saito, H. (1994). Differential effects of ginsenoside Rb1 and malonylginsenoside Rb1 on long-term potentiation in the dentate gyrus of rats. *Brain Research*, 649(1–2), 7–11. [https://doi.org/10.1016/0006-8993\(94\)91042-1](https://doi.org/10.1016/0006-8993(94)91042-1)
- Baek, J. H., Heo, J. Y., Fava, M., Mischooulon, D., Choi, K. W., Na, E. J., Cho, H., & Jeon, H. J. (2019). Effect of Korean Red Ginseng in individuals exposed to high stress levels: A 6-week, double-blind, randomized, placebo-controlled trial. *J Ginseng Res*, 43(3), 402–407. <https://doi.org/10.1016/j.jgr.2018.03.001>
- Barry, R. J., Clarke, A. R., Johnstone, S. J., Magee, C. A., & Rushby, J. A. (2007). EEG differences between eyes-closed and eyes-open resting conditions. *Clinical neurophysiology*, 118(12), 2765–2773.
- Bell, L., Whyte, A., Duysburgh, C., Marzorati, M., Van den Abbeele, P., Le Cozannet, R., Fança-Berthon, P., Fromentin, E., & Williams, C. (2021). A randomized, placebo-controlled trial investigating the acute and chronic benefits of American Ginseng (Cereboost®) on mood and cognition in healthy young adults, including in vitro investigation of gut microbiota changes as a possible mechanism of action. *European Journal of Nutrition*(1). <https://doi.org/10.1007/s00394-021-02654-5>
- Bell, L., Fança-Berthon, P., Cozannet, R. L., Ferguson, D., Scholey, A., & Williams, C. (2026). Effects of American ginseng (*Panax quinquefolius*) extract on human neurocognitive function: a review. *Nutritional Neuroscience*, 29(2), 213–223. <https://doi.org/10.1080/1028415X.2025.2555921>
- Benishin, C., Lee, R., Wang, L., & Liu, H. (1991). Effects of Ginsenoside Rb1 on central cholinergic metabolism. *Pharmacology*, 42, 223–229. <https://doi.org/10.1159/000138801>
- Bokelmann, J. M. (2022). Ginsengs: Asian/Korean/Chinese (*Panax ginseng*) and American (*Panax quinquefolius*). In *Medicinal Herbs in Primary Care* (pp. 385–407). <https://doi.org/10.1016/B978-0-323-84676-9.00049-0>
- Cardinal, B. J., & Engels, H. J. (2001). Ginseng does not enhance psychological well-being in healthy, young adults: Results of a double-blind, placebo-controlled, randomized clinical trial. *Journal of the American Dietetic Association*, 101(6), 655–660. [https://doi.org/10.1016/S0002-8223\(01\)00165-1](https://doi.org/10.1016/S0002-8223(01)00165-1)
- Chen, E. Y., & Hui, C. L. (2012). HT1001, a proprietary North American ginseng extract, improves working memory in schizophrenia: A double-blind, placebo-controlled study. *Phytotherapy Research*, 26(8), 1166–1172. <https://doi.org/10.1002/ptr.3700>
- Chen, C. F., Chiou, W. F., & Zhang, J. T. (2008). Comparison of the pharmacological effects of *Panax ginseng* and *Panax quinquefolium*. *Acta Pharmacologica Sinica*, 29(9), 1103–1108. <https://doi.org/10.1111/j.1745-7254.2008.00868.x>
- Chen, W., Li, X., Chen, Z., Hao, W., Yao, P., Li, M., Liu, K., Hu, H., Wang, S., & Wang, Y. (2022). A comprehensive quality analysis of randomized controlled clinical trials of Asian ginseng and American ginseng based on the CONSORT guideline. *Journal of Ginseng Research*, 46(1), 71–78. <https://doi.org/10.1016/j.jgr.2021.05.003>
- Choi, M.-K., Jin, S., Jeon, J.-H., Kang, W. Y., Seong, S. J., Yoon, Y.-R., Han, Y.-H., & Song, I.-S. (2020). Tolerability and pharmacokinetics of ginsenosides Rb1, Rb2, Rc, Rd, and compound K after single or multiple administration of red ginseng extract in human beings. *Journal of Ginseng Research*, 44(2), 229–237.
- Chu, S. F., & Zhang, J. T. (2009). New achievements in ginseng research and its future prospects. *Chinese Journal of Integrative Medicine*, 15(6), 403–408. <https://doi.org/10.1007/s11655-009-0403-6>
- Churchill, J. D., Gerson, J. L., Hinton, K. A., Mifek, J. L., Walter, M. J., Winslow, C. L., & Deyo, R. A. (2002). The nootropic properties of ginseng saponin Rb1 are linked to effects on anxiety [Psychopharmacology 2580]. *Integrative Physiological & Behavioral Science*, 37(3), 178–187. <https://doi.org/10.1007/BF02734180>
- D'Angelo, L., Grimaldi, R., Caravaggi, M., Marcoli, M., Perucca, E., Lecchini, S., Frigo, G. M., & Crema, A. (1986). A double-blind, placebo-controlled clinical study on the effect of a standardized ginseng extract on psychomotor performance in healthy volunteers. *Journal of Ethnopharmacology*, 16(1), 15–22. [https://doi.org/10.1016/0378-8741\(86\)90063-2](https://doi.org/10.1016/0378-8741(86)90063-2)
- Fulder, S. (Ed.). (1990). *The book of ginseng*.
- Hiai, S., Yokoyama, H., Oura, H., & Kawashima, Y. (1983). Evaluation of corticosterone secretion-inducing activities of ginsenosides

- and their prosapogenins and sapogenins. *Chemical & Pharmaceutical Bulletin*, 31(1), 168. <https://doi.org/10.1248/cpb.31.168>
- Kennedy, D. O., & Scholey, A. B. (2003). Ginseng: Potential for the enhancement of cognitive performance and mood. *Pharmacology, Biochemistry and Behavior*, 75(3), 687–700. [https://doi.org/10.1016/s0091-3057\(03\)00126-6](https://doi.org/10.1016/s0091-3057(03)00126-6)
- Kennedy, D. O., Scholey, A. B., & Wesnes, K. A. (2001). Dose dependent changes in cognitive performance and mood following acute administration of Ginseng to healthy young volunteers. *Nutritional Neuroscience*, 4(4), 295–310. <https://doi.org/10.1080/1028415x.2001.11747370>
- Kennedy, D. O., Scholey, A. B., & Wesnes, K. A. (2002). Modulation of cognition and mood following administration of single doses of *Ginkgo biloba*, ginseng, and a ginkgo/ginseng combination to healthy young adults. *Physiology & Behavior*, 75(5), 739–751. [https://doi.org/10.1016/s0031-9384\(02\)00665-0](https://doi.org/10.1016/s0031-9384(02)00665-0)
- Kennedy, D., Scholey, A., Drewery, L., Marsh, R., Moore, B., & Ashton, H. (2003). Topographic EEG effects of single doses of *Panax ginseng* and *Ginkgo biloba*. *Pharmacology Biochem and Behav*, 75, 701–709. [https://doi.org/10.1016/s0091-3057\(03\)00120-5](https://doi.org/10.1016/s0091-3057(03)00120-5)
- Kennedy, D. O., Haskell, C. F., Wesnes, K. A., & Scholey, A. B. (2004). Improved cognitive performance in human volunteers following administration of guarana (*Paullinia cupana*) extract: Comparison and interaction with *Panax ginseng*. *Pharmacology, Biochemistry And Behavior*, 79(3), 401–411. <https://doi.org/10.1016/j.pbb.2004.07.014>
- Kennedy, D. O., Reay, J. L., & Scholey, A. B. (2007). Effects of 8 weeks administration of Korean *Panax ginseng* extract on the mood and cognitive performance of healthy individuals. *J Ginseng Res*, 31(1), 34–43. <https://doi.org/10.5142/JGR.2007.31.1.034>
- Ko, H. J., Kim, I., Kim, J. B., Moon, Y., Whang, M. C., Lee, K. M., & Jung, S. P. (2014). Effects of Korean red ginseng extract on behavior in children with symptoms of inattention and hyperactivity/impulsivity: A double-blind randomized placebo-controlled trial [Developmental Disorders & Autism 3250]. *Journal Of Child And Adolescent Psychopharmacology*, 24(9), 501–508. <https://doi.org/10.1089/cap.2014.0013>
- LaSala, G. S., McKeever, R. G., Patel, U., Okaneku, J., Vearrier, D., & Greenberg, M. I. (2015). Effect of single-dose *Ginkgo biloba* and *Panax ginseng* on driving performance [Article]. *Clinical Toxicology*, 53(2), 108–112. <https://doi.org/10.3109/15563650.2014.999159>
- Lee, J. W., Ji, S. H., Lee, Y. S., Choi, D. J., Choi, B. R., Kim, G. S., Baek, N. I., & Lee, D. Y. (2017). Mass spectrometry based profiling and imaging of various ginsenosides from *Panax ginseng* roots at different ages. *International journal of molecular sciences*, 18(6), 1114. <https://doi.org/10.3390/ijms18061114>
- Lyon, M. R., Cline, J. C., Totosty de Zepetnek, J., Shan, J. J., Pang, P., & Benishin, C. (2001). Effect of the herbal extract combination *Panax quinquefolium* and *Ginkgo biloba* on attention-deficit hyperactivity disorder: A pilot study [Article]. *Journal Of Psychiatry And Neuroscience*, 26(3), 221–228. <https://www.ncbi.nlm.nih.gov/pubmed/11394191>
- Mariage, P. A., Hovhannisyan, A., & Panossian, A. G. (2020). Efficacy of *Panax ginseng* Meyer Herbal Preparation HRG80 in Preventing and Mitigating Stress-Induced Failure of Cognitive Functions in Healthy Subjects: A Pilot, Randomized, Double-Blind, Placebo-Controlled Crossover Trial. *Pharmaceuticals (Basel)*, 13(4), 57. <https://doi.org/10.3390/ph13040057>
- Neale, C., Camfield, D., Reay, J., Stough, C., & Scholey, A. (2013). Cognitive effects of two nutraceuticals *Ginseng* and *Bacopa* benchmarked against modafinil: A review and comparison of effect sizes. *British Journal of Clinical Pharmacology*, 75(3), 728–737. <https://doi.org/10.1111/bcp.12002>
- Nitta, H., Matsumoto, K., Shimizu, M., Ni, X. H., & Watanabe, H. (1995). *Panax ginseng* extract improves the scopolamine-induced disruption of 8-arm radial maze performance in rats. *Biological & Pharmaceutical Bulletin*, 18(10), 1439–1442. <https://doi.org/10.1248/bpb.18.1439>
- Ong Lai Teik, D., Lee, X. S., Lim, C. J., Low, C. M., Muslima, M., & Aquili, L. (2016). Ginseng and *Ginkgo Biloba* effects on cognition as modulated by cardiovascular reactivity: A randomised trial. *PLoS One*, 11(3), Article e0150447. <https://doi.org/10.1371/journal.pone.0150447>
- Ossoukhova, A., Owen, L., Savage, K., Meyer, M., Ibarra, A., Roller, M., Pipingas, A., Wesnes, K., & Scholey, A. (2015). Improved working memory performance following administration of a single dose of American ginseng (*Panax quinquefolius* L.) to healthy middle-age adults. *Human Psychopharmacology*, 30(2), 108–122. <https://doi.org/10.1002/hup.2463>
- Park, K. C., Jin, H., Zheng, R., Kim, S., Lee, S. E., Kim, B. H., & Yim, S. V. (2019). Cognition enhancing effect of *panax ginseng* in Korean volunteers with mild cognitive impairment: A randomized, double-blind, placebo-controlled clinical trial [Article]. *Translational and Clinical Pharmacology*, 27(3), 92–97. <https://doi.org/10.12793/tcp.2019.27.3.92>
- Peng, X., Hao, M., Zhao, Y., Cai, Y., Chen, X., Chen, H., Zhang, Y., Dong, L., Liu, X., Ding, C., Liu, W., Yang, M., & Luo, Y. (2021). Red ginseng has stronger anti-aging effects compared to ginseng possibly due to its regulation of oxidative stress and the gut microbiota. *Phytomedicine*, 93, Article 153772. <https://doi.org/10.1016/j.phymed.2021.153772>
- Persson, J., Bringlov, E., Nilsson, L. G., & Nyberg, L. (2004). The memory-enhancing effects of Ginseng and *Ginkgo biloba* in healthy volunteers [Psychopharmacology 2580]. *Psychopharmacology (Berlin)*, 172(4), 430–434. <https://doi.org/10.1007/s00213-003-1675-8>
- Petkov, V. D., & Mosharrof, A. H. (1987). Effects of standardized ginseng extract on learning, memory and physical capabilities. *American Journal of Chinese Medicine*, 15(1–2), 19–29. <https://doi.org/10.1142/S0192415X87000047>
- Petkov, V. D., Kehayov, R., Belcheva, S., Konstantinova, E., Petkov, V. V., Getova, D., & Markovska, V. (1993). Memory effects of standardized extracts of *Panax ginseng* (G115), *Ginkgo biloba* (GK 501) and their combination Gincosan (PHL-00701) [Article]. *Planta Medica*, 59(2), 106–114. <https://doi.org/10.1055/s-2006-959623>
- Petkov, V. D., Belcheva, S., & Petkov, V. V. (2003). Behavioral effects of *Ginkgo biloba* L., *Panax ginseng* C.A. Mey. and Gincosan. *American Journal of Chinese Medicine*, 31(6), 841–855. <https://doi.org/10.1142/S0192415X03001533>
- Reay, J. L., Kennedy, D. O., & Scholey, A. B. (2005). Single doses of *Panax ginseng* (G115) reduce blood glucose levels and improve cognitive performance during sustained mental activity. *Journal of Psychopharmacology*, 19(4), 357–365. <https://doi.org/10.1177/0269881105053286>
- Reay, J., Kennedy, D., & Scholey, A. (2006). Effects of *Panax ginseng*, consumed with and without glucose, on blood glucose levels and cognitive performance during sustained mentally demanding tasks. *Journal of Psychopharmacology*, 20(6), 771. <https://doi.org/10.1177/0269881106061516>
- Reay, J. L., Scholey, A. B., & Kennedy, D. O. (2010). *Panax ginseng* (G115) improves aspects of working memory performance and subjective ratings of calmness in healthy young adults [Article]. *Human Psychopharmacology*, 25(6), 462–471. <https://doi.org/10.1002/hup.1138>
- Sakovics, J., Apor, P., & Zsidegh, M. (1977). Effect of *Panax ginseng* on neuromotor functions in humans [Article]. *Acta Physiologica Academiae Scientiarum Hungaricae*, 49(3–4), 343.

- Salim, K. N., McEwen, B. S., & Chao, H. M. (1997). Ginsenoside Rb1 regulates ChAT, NGF and trkA mRNA expression in the rat brain. *Brain Research. Molecular Brain Research*, 47(1–2), 177–182. [https://doi.org/10.1016/s0169-328x\(97\)00042-9](https://doi.org/10.1016/s0169-328x(97)00042-9)
- Scholey, A. (2018). Nutrients for neurocognition in health and disease: Measures, methodologies and mechanisms. *Proceedings of the Nutrition Society*, 77(1), 73–83. <https://doi.org/10.1017/S0029665117004025>
- Scholey, A., & Kennedy, D. (2002). Acute, dose-dependent cognitive effects of *Ginkgo biloba*, *Panax ginseng* and their combination in healthy young volunteers: Differential interactions with cognitive demand. *Human Psychopharmacology: Clinical and Experimental*, 17(1), 35–44. <https://doi.org/10.1002/hup.352>
- Scholey, A., Ossoukhova, A., Owen, L., Ibarra, A., Pipingas, A., He, K., Roller, M., & Stough, C. (2010). Effects of American ginseng (*Panax quinquefolius*) on neurocognitive function: An acute, randomised, double-blind, placebo-controlled, crossover study. *Psychopharmacology (Berl)*, 212(3), 345–356. <https://doi.org/10.1007/s00213-010-1964-y>
- Shi, Z. Y., Zeng, J. Z., & Wong, A. S. T. (2019). Chemical structures and pharmacological profiles of ginseng saponins. *Molecules*, 24(13), Article 2443. <https://doi.org/10.3390/molecules24132443>
- Smith, I., Williamson, E. M., Putnam, S., Farrimond, J., & Whalley, B. J. (2014). Effects and mechanisms of ginseng and ginsenosides on cognition. *Nutrition Reviews*, 72(5), 319–333. <https://doi.org/10.1111/nure.12099>
- Sünram-Lea, S., Birchall, R., Wesnes, K., & Petrini, O. (2004). The effect of acute administration of 400 mg of *Panax ginseng* on cognitive performance and mood in healthy young volunteers. *Current Topics in Nutraceutical Research*, 3(1), 251–254.
- Tachikawa, E., Kudo, K., Harada, K., Kashimoto, T., Miyate, Y., Kakizaki, A., & Takahashi, E. (1999). Effects of ginseng saponins on responses induced by various receptor stimuli. *European Journal of Pharmacology*, 369(1), 23–32. [https://doi.org/10.1016/s0014-2999\(99\)00043-6](https://doi.org/10.1016/s0014-2999(99)00043-6)
- Tardy, A.-L., Bois De Fer, B., Cañigual, S., Kennedy, D., Scholey, A., Hitier, S., Aran, A., & Pouteau, E. (2021). Reduced self-perception of fatigue after intake of *Panax ginseng* root extract (G115®) formulated with vitamins and minerals—an open-label study. *International Journal of Environmental Research and Public Health*, 18(12), Article 6257. <https://doi.org/10.3390/ijerph18126257>
- Tsang, D., Yeung, H. W., Tso, W. W., & Peck, H. (1985). Ginseng saponins: Influence on neurotransmitter uptake in rat brain synaptosomes. *Planta Medica*, 51(3), 221–224. <https://doi.org/10.1055/s-2007-969463>
- Vandenhouten Eric, E., Yan, L., & Wang, Y. (2019). Pharmacological and clinical efficacy of American ginseng (*Panax quinquefolius*): A mini review. *International Journal of Chinese Medicine*, 3(4), Article 64. <https://doi.org/10.11648/j.ijcm.20190304.13>
- Wen, T., Yoshimura, H., Matsuda, S., Lim, J., & Sakanaka, M. (1995). Ginseng root prevents learning disability and neuronal loss in gerbils with 5-minute forebrain ischemia. *Acta Neuropathologica*, 91(1), 15–22. <https://doi.org/10.1007/s004010050387>
- White, D. J., Camfield, D. A., Ossoukhova, A., Savage, K., Le Cozannet, R., Fanca-Berthon, P., & Scholey, A. (2020). Effects of *Panax quinquefolius* (American ginseng) on the steady state visually evoked potential during cognitive performance. *Human Psychopharmacology: Clinical and Experimental*, 35(6), 1–6. <https://doi.org/10.1002/hup.2756>
- Zhao, R., & McDaniel, W. F. (1998). Ginseng improves strategic learning by normal and brain-damaged rats. *Neuroreport*, 9(7), 1619–1624. <https://doi.org/10.1097/00001756-199805110-00066>

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