

Original research paper

The effect of acute caffeine ingestion on coincidence anticipation timing in younger and older adults

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Objectives: This study compared the effect of acute caffeine ingestion on coincidence timing accuracy in younger and older adults.

Methods: Thirteen young (aged 18–25 years, age: 20 ± 2 years, 7 females, 5 males) and 13 older (aged 61–77 years, age: 68 ± 6 years, 9 females, 3 males) adults, all who were habitual moderate caffeine consumers undertook measures of coincident anticipation timing performance pre- and post-acute caffeine (3 mg/kg) or placebo ingestion administered in a double blind, randomized fashion.

Results: Results indicated significant pre-to-post X substance (caffeine vs. placebo) interactions for absolute ($P = 0.02$, $P\eta^2 = 0.204$) and variable error ($P = 0.015$, $P\eta^2 = 0.221$). In both cases, error (absolute or variable) improved pre-to-post ingestion in the caffeine condition but not in the placebo condition. There were no significant differences due to age (younger vs. older adults, $P > 0.05$) in any of the analyses.

Discussion: The results of this study suggest that acute caffeine ingestion positively influence coincidence anticipation timing performance in both younger and older adults, who are moderate habitual caffeine consumers. Such effects might therefore be useful for older adults in enhancing ability to undertake cognitive-perceptual tasks which involve interceptive actions.

Keywords: Caffeine, Ergogenic, Perception–action coupling, Ageing

Introduction

Caffeine is the single most widely consumed psychoactive ingredient in the world¹ with its popularity being attributed to its acute benefits for physical, psychomotor, and cognitive performance and mood state.² A recent review highlighted that caffeine improves performance on attentional tasks, but that the data are equivocal and consensus about the specific effects of caffeine on human performance has not been reached.² However, the majority of studies on this topic tends to employ young adults with the effect of caffeine ingestion on cognitive performance in older adults being less widely studied. Of those that have examined older adults, some have reported no improvements in measures of cognitive or attentional performance.^{3,4} Conversely, others have reported improvements in cognitive/attentional performance in older adults following caffeine ingestion.^{5,6} These studies^{5,6} have subsequently suggested that older

adults are more susceptible to the performance-enhancing effects of caffeine than younger adults.

As the ingestion of dietary caffeine is prevalent across the whole spectrum of society and with an ageing population worldwide, authors have suggested that nutritional ergogenic aids such as caffeine may be useful in enhancing functionality, cognition, tasks of daily living, and psychological well-being in older adults.⁷ One particular facet of performance, which has received little attention both in respect to the effects of age and the effect of caffeine ingestion is coincidence anticipation timing (CAT). CAT contributes to success in numerous tasks of daily living, but particularly where predicting the arrival of a moving object is important, e.g. crossing a busy street.⁸ As such, CAT can be regarded as a measure of perception–action coupling, involving both cognitive and motor processes.⁸ Understanding the effect of age on CAT is important as older adults have been reported to be increasingly affected in such timing tasks.^{9,10} Moreover, age related increases in timing errors have been speculated as key in reducing accidents in older

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adults,¹¹ a population at greater risk of accidents during tasks of daily living.¹² No studies appear to have examined whether caffeine ingestion influences timing performance. However, one study to date has reported on CAT performance in older adults.¹² Lobjois *et al.*¹² reported that older, non-tennis playing adults had significantly poorer CAT performance compared with tennis playing older and younger adults. However, the effect of nutritional ergogenics on timing performance in older adults has not yet been examined, despite previous research indicating that ingesting substances such as caffeine may have a more pronounced effect in older adults compared with younger adults by promoting greater energy reserve availability.^{13,14}

Thus, it is not currently clear to what extent caffeine ingestion might enhance timing performance in older compared with younger adults and as timing accuracy is important in tasks of daily living, the aim of this study was therefore to compare the effect of acute caffeine ingestion on CAT in younger and older adults.

Materials and methods

Participants

Following approval from the institutional ethics committee and informed consent, 13 young adults (aged 18–25 years, age: 20 ± 2 years, 7 females, 5 males) and 13 older adults (aged 61–77 years, age: 68 ± 6 years, 9 females, 3 males) volunteered to participate. All participants habitually ingested caffeine, although none was a heavy caffeine user (>350 mg/day, mean \pm SD of caffeine consumption = 105.6 ± 46.3 mg/day for younger adults and 100.2 ± 25.2 mg/day for older adults, $P > 0.05$). Participants were excluded if they had any cardiovascular condition, were taking medications such as beta-blockers or calcium ion channel blockers, were heavy habitual caffeine users or were caffeine naive. Participants were asked to abstain from caffeine intake and exercise for 48 hours prior to each visit and undertook three visits to the human performance laboratory. In the first visit, they were familiarized with the equipment and procedures involved in the study. In the following two experimental trials, participants completed measures of CAT pre- and 60 minutes post-caffeine or placebo ingestion. Each visit to the laboratory was separated by at least 72 hours.

Experimental procedures

Following familiarization, participants attended the laboratory on two occasions in a randomized order. On arrival, participants completed 'pre ingestion' trials on the coincidence anticipation timer and then ingested either 3 mg/kg body mass of caffeine (Bayer, UK) diluted into 250 ml of artificially sweetened water or a placebo condition (250 ml of

artificially sweetened water). Solutions were presented to participants in an opaque sports bottle and were matched for taste prior to the experimental trials. Solutions were administered double blind and consumed 60 minutes before each trial as plasma caffeine concentration is maximal 60 minutes after ingestion of caffeine.¹⁵ Following this, participants undertook 'post ingestion' trials on the coincidence anticipation timer.

CAT assessment

The Bassin anticipation timer (Model 35575, Lafayette, USA) was used to assess coincidence anticipation performance in the present study. CAT refers to the ability to predict the arrival of a moving object at a particular point in space and coordinate a movement response with that arrival.¹⁶ As such it can be considered a test of perceptual-motor coupling requiring integration of sensory-cognitive procession and sensory-motor integration.¹⁷ It is fundamental to a multitude of actions within daily life including making judgements of when to shake hands, pick up a cup, catch a moving object, or walk through a crowd of shoppers.⁸

During the familiarization session, participants were given 20 attempts at a stimulus speed of 5 mph to familiarize themselves with the test protocol. The Bassin Anticipation Timer was set up vertically (i.e. placed towards/away) from the front of the participant with the target stimulus moving distally to proximally. Three sections of runway (2.24 m in total length) with the system's light-emitting diode (LED) lights facing the participant were used and the target light was light #13. The sequentially lighted LED lamps illuminate in a linear pattern with movement occurring distally to proximally in front of the participant. For each trial, scores were recorded in seconds. Start and end speeds were 5 mph for all trials to represent medium stimulus speeds, as has been used in prior studies,¹² using a random cue delay (minimum delay = 1 second, maximum delay = 2 seconds) the signal was initiated by the experimenter, with the participant being asked to press a trigger button, using their dominant hand, as close to the arrival time of the stimulus at the target location as possible. Participants completed 10 trials pre and post-substance ingestion in each condition. Scores across each of the stimulus speeds were summarized into three error scores as a means of generating the dependent variables. This is consistent with recognized protocols using coincidence timing.^{8,18} The dependent measures were as follows:

Constant error: The temporal interval (in milliseconds) between the arrival of the visual stimulus and the end of the participant's motor response. It represents the mean response of an individual and the direction of error: early or late.¹⁹

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Variable error: The participant's standard deviation from their mean response; this represents the variability/inconsistency of responses.

Absolute error: The absolute value of each raw score disregarding whether the response was early or late. However, when data were checked for normality, scores for variable and absolute error were positively skewed in all cases (all the values are positive). To correct for skewness, the dataset were log transformed as log transforming data in this way has been shown to overcome skewness in previous work.²⁰ These data were then used in all subsequent statistical analysis.

Statistical analysis

A series of 2 (young vs. old) × 2 (pre-to-post ingestion) × 2 (caffeine vs. placebo) ways repeated measures analysis of variance were conducted to examine any differences in constant error, variable error, and absolute error on the CAT task. Where significant differences were found, Bonferroni *post hoc* pairwise comparisons were used to determine where the differences lay. Partial eta-squared ($P\eta^2$) was also used as a measure of effect size. The Statistical Package for Social Sciences (SPSS, Version 20, Chicago, IL, USA) was used for all analysis and statistical significance was set, a priori, at $P = 0.05$. Data are reported as mean ± SE.

Results

The results indicated no significant main effects or interactions for constant error (all $P < 0.05$). There were also no main significant effect pre-to-post ($P = 0.254$) for substance (caffeine vs. placebo) ($P = 0.242$) or between older and younger adults ($P = 0.866$) for absolute error. Likewise, there was no main significant effects pre-to-post ($P = 0.816$), for substance ($P = 0.08$) or between older and younger adults ($P = 0.628$) for variable error. However, there were significant pre-to-post X substance interactions for absolute error ($F_{1,23} = 6.158$, $P = 0.02$, $P\eta^2 =$

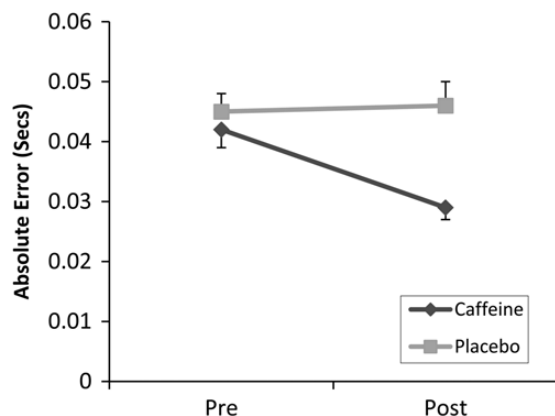


Figure 1 Mean ± SE of absolute error (seconds) pre- and post-caffeine ingestion in younger and older adults.

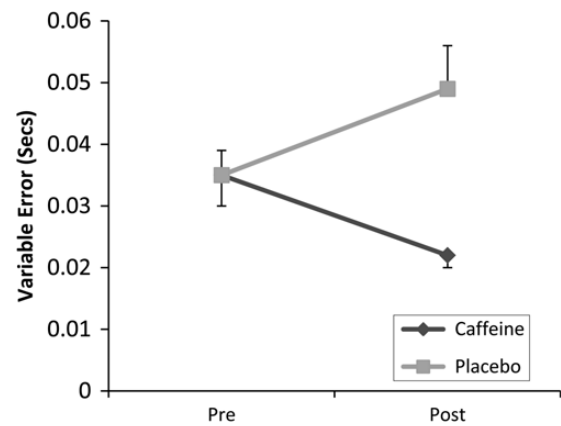


Figure 2 Mean ± SE of variable error (seconds) pre- and post-caffeine ingestion in younger and older adults.

0.204, see Fig. 1) and variable error ($F_{1, 23} = 6.79$, $P = 0.015$, $P\eta^2 = 0.221$, see Fig. 2). In both cases, error (absolute or variable) improved pre-to-post ingestion in the caffeine condition but either remained the same (absolute error) or became poorer (variable error, $P > 0.05$), in the placebo trial. Mean (95% confidence intervals) for constant, absolute, and variable error pre- and post-caffeine and placebo ingestion for older and younger adults are presented in Table 1.

Discussion

The results of this study are novel in that it examined the effect of acute caffeine ingestion on coincidence timing performance in a group of older and younger adults matched for habitual caffeine intake, a facet of prior studies that has been poorly considered. The current results suggest that acute caffeine ingestion (3 mg/kg) results in a significant improvement in absolute error scores and less variability in error compared with placebo ingestion in both younger and older adults. These responses were not different in younger and older groups.

CAT contributes to success in numerous tasks of daily living.⁹ Therefore, the results of this study suggest that acute caffeine ingestion is as effective in enhancing CAT performance in older and younger adults and therefore might have potential in enhancing tasks of daily living in older adults. When considering the magnitude of the differences reported in this study, it is also important to consider whether the differences in absolute error and variable error are meaningful. The Bassin anticipation timer was employed as this is the most precise, reliable, and validated measure of CAT available,⁸ has been validated against dynamic visual acuity in both children and adults²¹ and has been shown to reliably detect temporal differences of 0.0001 ms.²² The differences found in the present study are also commensurate with durations reported for timing of catching actions when stimuli are sighted, where a difference of 0.01 ms has been

Table 1 Mean (95% confidence intervals) of constant error, absolute error, and variable error between caffeine and placebo conditions pre- and post-ingestion in younger and older adults

		Caffeine			Placebo		
		Constant error (ms)	Absolute error (ms)	Variable error (ms)	Constant error (ms)	Absolute error (ms)	Variable error (ms)
Younger adults	Pre-ingestion	0.001 (−0.011 to 0.011)	0.045 (0.036–0.054)	0.042 (0.028–0.055)	−0.005 (−0.020 to 0.010)	0.041 (0.034–0.047)	0.031 (0.020–0.041)
	Post-ingestion	−0.005 (−0.016 to 0.006)	0.032 (0.026–0.039)	0.020 (0.014–0.027)	−0.011 (−0.029 to 0.006)	0.050 (0.036–0.064)	0.058 (0.027–0.088)
Older adults	Pre-ingestion	0.006 (−0.005 to 0.016)	0.040 (0.031–0.049)	0.028 (0.015–0.042)	−0.002 (−0.017 to 0.012)	0.048 (0.041–0.055)	0.040 (0.030–0.051)
	Post-ingestion	0.006 (−0.006 to 0.017)	0.030 (0.024–0.036)	0.026 (0.020–0.032)	0.016 (−0.002 to 0.034)	0.047 (0.033–0.062)	0.042 (0.012–0.073)

identified as the temporal difference between unsuccessful and successful catching of a moving projectile.²³ Thus, the small temporal differences of 0.011 and 0.03 seconds reported here for absolute and variable error, respectively, may be considered as meaningful in the context of CAT. These results add support to prior claims that caffeine ingestion may enhance performance where cognitive and/or perceptual-motor skills are important.^{24,25} To some extent the positive impact of caffeine ingestion on such performance is not unexpected. Caffeine ingestion has measureable performance-enhancing abilities.²⁶ This is in part due to its impact on the central nervous system (CNS),²⁷ through adenosine inhibition.²⁶ However, to date no studies appear to have examined whether the caffeine ingestion influences timing performance. In this respect, these data may be considered the novel aspect of this study and is important as older adults have been reported to be increasingly affected in tasks where intercepting a moving stimulus^{9,10} and improving timing accuracy may have accident risk reduction benefits.¹¹ As there are no studies reporting the impact of caffeine ingestion on coincidence timing performance, specifically it is difficult to compare the results presented here with prior research. One paper¹² has, however, reported that older adults had significantly poorer CAT performance, compared with younger adults, at a stimulus speed similar to that used in the present study, represented by scores for variable and constant error. Surprisingly, Lobjois *et al.*¹² did not report scores for absolute error although this is the more commonly accepted measure of timing error in the literature.⁸ There are some explanations for the results presented here. As the timing tasks in the present study were performed at rest, the effect of caffeine on the CNS may therefore have allowed greater attentional capacity during the timing trials and producing enhanced timing performance. Such a suggestion is congruent with prior work, suggesting more effective attentional focusing is one of

the main mechanisms by which caffeine enhances cognitive and perceptual performance.^{2,24} The increased attentional capacity resulting from ingestion of a CNS activator may therefore enable more focused allocation of resources to a given task than without caffeine.

In order to contextualize the broader application of these findings, the limitations to this study should be considered. The data presented here relate to a bolus of caffeine equating to 3 mg/kg. In other studies, both higher and lower doses of caffeine have been shown to be ergogenic in various cognitive and attentional tasks.^{3–6} Comparing any dose–response relationships of caffeine on timing performance would therefore be useful in future research, especially in older adults. Also, the participants in the present study were moderate caffeine users, who abstained from caffeine ingestion for 48 hours prior to engaging in the experimental procedures. Recent research has highlighted that when this protocol is employed, any effects seen may be as a result of a normalization effect following the negative effects of caffeine withdrawal.²⁸ Future research should therefore take this issue into consideration when attempting to understand the impact of caffeine ingestion on cognitive and perceptual performance. Another important consideration also is the fact that the motion of the Bassin anticipation timer may not be fully comparable with the anticipatory demands of some of the skills needed in daily life.⁸ The Bassin anticipation timer was employed as this is the most widely validated measure of CAT currently available.⁸ It would therefore be desirable for future research to employ more specific coincident timing protocols (e.g. simulating crossing a road) and to examine coincidence anticipation responses to exercise using non-uniform and non-linear motion. In this way the results presented here could be developed to better evidence ecological validity of acute caffeine ingestion on timing performance.

Conclusions

The results of this study suggest that acute caffeine ingestion positively influence CAT performance in both younger and older adults, who are moderate habitual caffeine consumers. Such effects might therefore be useful for older adults in enhancing ability to undertake tasks which involve interceptive actions.

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