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Dose-response effects of water supplementation on cognitive performance and mood in children and adults

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ABSTRACT

Water supplementation has been found to facilitate visual attention and short-term memory, but the dose required to improve performance is not yet known. We assessed the dose response effect of water on thirst, mood and cognitive performance in both adults and children. Participants were offered either no water, 25 ml or 300 ml water to drink. Study 1 assessed 96 adults and in Study 2, data are presented from 60 children aged 7–9 years. In both studies, performance was assessed at baseline and 20 min after drinking (or no drink); on thirst and mood scales, letter cancellation and a digit span test. For both children and adults, a large drink (300 ml) was necessary to reduce thirst, while a small drink (25 ml) was sufficient to improve visual attention (letter cancellation). In adults, a large drink improved digit span, but there was no such effect in children. In children, but not adults, a small drink resulted in increased thirst ratings. Both children and adults show dose-response effects of drinking on visual attention. Visual attention is enhanced by small amounts of fluid and appears not to be contingent on thirst reduction. Memory performance may be related to thirst, but differently for children and adults. These contrasting dose-response characteristics could imply cognitive enhancement by different mechanisms for these two domains.

1. Introduction

While there is agreement that certain cognitive processes and mood states are facilitated by drinking water (Benton et al., 2015; Masento, Golightly, Field, Butler, & van Reekum, 2016), there are conflicting findings in the literature. This may be a result of differences in the amount of water offered across studies with resulting differential dose response effects on performance. This paper reports two studies that investigate the dose response effect of water consumption on cognitive performance and mood in both adults and children.

Studies in children have reported that visual attention, measured by performance on a letter cancellation task, is improved by drinking 250 ml (Booth, Taylor, & Edmonds, 2012; Edmonds & Burford, 2009) or 500 ml water (Edmonds & Jeffes, 2009). Drinking 250 ml or 300 ml water has been found to improve children's performance on tasks assessing visual memory (Benton & Burgess, 2009; Edmonds & Burford, 2009) and an increase in water consumption over a whole day has been associated with better digit span (Fadda et al., 2012; an average of 624 ml over a school day). In contrast, children's memory for stories (Edmonds & Burford, 2009; Edmonds & Jeffes, 2009), visuomotor tracking (Edmonds & Burford, 2009; Edmonds & Jeffes, 2009), or sustained attention tasks (Benton & Burgess, 2009) have not been found to be affected by water consumption.

In the case of adults, 200 ml water has been found to improve visual attention (Edmonds, Crombie, Ballieux, Gardner, & Dawkins, 2013) (measured by letter cancellation) and 500 ml has been shown to shorten reaction time (Edmonds, Crombie, & Gardner, 2013). However, studies have also reported that water did not improve performance on tasks assessing memory (Edmonds, Crombie, & Gardner, 2013; Neave et al., 2001), set shifting (Edmonds, Crombie, & Gardner, 2013), or attention (Edmonds, Crombie, & Gardner, 2013; Neave et al., 2001). Moreover, one study suggested that performance on a set shifting task was not affected by drinking water, and was better if participants reported themselves to be

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thirsty (Edmonds, Crombie, & Gardner, 2013). Other studies have also reported that the effect of drinking water is influenced by participants' thirst. For example, adults' performance on a rapid visual information processing task was improved after drinking either 120 ml or 330 ml water, but only if they initially rated themselves as thirsty (Rogers, Kainth, & Smit, 2001); if they initially rated themselves as not thirsty, consuming water resulted in poorer performance. Similarly, reaction times of adults who rate themselves as less thirsty, were not found to be affected by water supplementation, while the reaction time of thirsty individuals sped up after drinking water (Edmonds, Crombie, & Gardner, 2013).

In the case of mood, inconsistent effects of water supplementation have been reported. Subjective feelings of alertness and concentration have been found to be higher in adults who have free access to water compared to a group on a restricted drinking regime (Shirrefs, Merson, Fraser, & Archer, 2004). Moreover, adults have rated themselves as more alert after acute water ingestion (Rogers et al., 2001). Other studies have reported no effect of water on adults' subjective ratings of mood (Edmonds, Crombie, Ballieux, et al., 2013). In the case of children, there is some evidence to suggest that those who drank water rated themselves as happier compared to those who drank nothing (Edmonds & Jeffes, 2009), although it is possible that this is due to diminishing the discomfort associated with thirst.

The studies reviewed above show somewhat inconsistent findings with regards to the effect of water consumption on cognition and mood, but they also offer inconsistent amounts of water. A dose response effect, that has yet to be investigated, could potentially explain disparities. However, without systematically surveying the literature, we do not yet have the evidence to claim that the literature support this. Our review of the literature is suggestive that performance on a visual attention task (letter cancellation) seems to occur irrespective of dose, while improvements on a memory task (digit span) seem to require a larger dose of water; thus, different systems may be sensitive to different doses of water. Here, we report an investigation of the dose response characteristics of the effects of acute water supplementation on cognitive performance and mood. We seek to test the generality of the phenomenon by assessing both adults (Study 1) and children (Study 2) given that these are the two populations commonly used in these studies. We explored this systematically in adults and children, using visual attention (letter cancellation) and memory (digit span) tasks that have been employed in previous studies.

2. Study 1: Adults

The aim of Study 1 was to evaluate the dose response effect of water on cognitive performance and mood in adults. We manipulated the volume of water offered to participants, offering either a large drink (300 ml) a small drink (25 ml) or no drink, and examined the effect on performance on measures of visual attention and memory, and subjective ratings of thirst and mood.

3. Methods

3.1. Participants

Ninety-six participants were recruited from the student population at the University of Westminster. There was no monetary or other incentive to take part. Each of the three groups consisted of 32 participants. The mean age of participants was 21.0 years in each group (300 ml, *SD* = 2.5 years; 25 ml, *SD* = 3.6 years; no water, *SD* = 2.8 years). There were more females than males overall, but the ratio of males to females was similar in each group (300 ml, F = 22; 25 ml, F = 25; no water, F = 21).

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving adult participants were approved by the ethics committee of the Department of Psychology, University of Westminster. Written informed consent was obtained from all participants.

3.2. Measures

3.2.1. Thirst scales

To indicate subjective thirst, participants marked a horizontal line with anchors stating “not thirsty at all” and “very thirsty”. Scores were calculated by measuring the line starting from “not at all thirsty”. Scores were expressed as percentages and a higher score indicates a higher level of subjective thirst.

3.2.2. Mood scale

To assess mood, participants marked a horizontal line with anchors stating, “very sad” and “very happy” to indicate their current subjective happiness. Scores were expressed as percentages and higher scores were associated with a more positive mood.

3.2.3. Letter cancellation

This was a pencil and paper test. Participants had to cross through examples of a target letter (“U”) in a 20 × 20 grid as quickly as possible, within 20 s. The grid was filled with targets (n = 38) and distractor letters (“O”, n = 323; “V”, n = 28; “C”, n = 11). The score was the number of correctly identified letters minus incorrectly checked letters and the maximum score was 38. A higher score indicated better performance.

3.2.4. Digit span

A series of digits were read aloud by the researcher at a rate of 1 digit every two seconds. Participants were required to repeat the sequence in the order that it was presented. Sequences were initially three digits in length, and increased by one digit until a maximum of ten digits was reached.

Adults were required to repeat the sequence back to the experimenter out loud. There were two trials at each sequence length, and the test proceeded if at least one were answered correctly; the task was stopped when participants failed to correctly repeat two consecutive sequences.

3.3. Procedure

All participants completed the thirst and mood scale, followed by baseline cognitive tests. They were then offered either 25 ml, 300 ml, or no water and were encouraged to drink the full amount, which all of them did. After water consumption there was an interval of approximately 20 min, which is the interval commonly reported in the literature reviewed above, during which the participants spent time quietly. Following the interval, participants completed the second set of scales and cognitive tests. Parallel forms of the cognitive tests were used and the order of these was counterbalanced. Upon completion participants were thanked and debriefed. Adult participants were tested individually in a quiet room.

Statistical Analysis. For both studies, a mixed model ANOVA (TIME x VOLUME) were conducted for each outcome variable. Analyses comparing baseline and test scores were carried out at each volume level in accordance with the hypotheses. The Bonferroni correction for multiple tests was employed and the alpha level was set at 0.017 (0.05/3 comparisons).