Paula Booth is a PhD student at the School of Psychology, The University of East London. Bianca Taylor was a student at the University of East London and Dr Caroline Edmonds is a Senior Lecturer at the School of Psychology, The University of East London.
For communication please email: p.booth@uel.ac.uk

Paula Booth, Bianca Taylor and Caroline Edmonds

Water supplementation improves visual attention and fine motor skills in schoolchildren

This paper addresses a gap in the literature on the effects of water supplementation on visual attention and motor performance in schoolchildren. There has been extensive research showing that dehydration in adults is associated with detrimental effects on cognitive performance. Furthermore, studies of schoolchildren found that those that arrived at school with a hydration deficit performed worse in cognitive tasks than those children who were better hydrated (see Edmonds, 2012, for review). This is a concern because a recent study of 452 UK schoolchildren, aged between 9 and 11 years old, suggested that 60% of children arrive at school insufficiently hydrated (Barker et al, 2012). These results are consistent with similar studies from France and Israel in which two thirds of the children, of the same age, were insufficiently hydrated at the beginning of the school day (Bonnet et al, 2012; Edmonds, 2012).

Drinking water at school

Once children have arrived at school the evidence suggests that they are not drinking sufficient water throughout the day to counteract the risk of dehydration or even to maintain the hydration level that they had when they arrived at school. Kaushik et al. (2007) recruited 298 participants from Years 2 and 5 from six UK schools. The total volume of fluid drunk by each child per day was recorded and results suggested that 71% of children did not drink the minimum fluid required in a school day to maintain their hydration level. This evidence is consistent with the results from a survey of fluid intake of 1,456 adults and children living throughout the UK (Gandy, 2012). All beverages consumed over a period of 7 days were recorded and the results showed that 56% of children between the ages of 7 and 10 years old were not consuming the European adequate intake.

Adequate Intake (AI) is the observed amount of fluid consumed by different population groups who have a healthy hydration status. The observed mean amount of fluid consumption is then recommended for each population group. The European Food Safety Authority (EFSA) recommends that boys between the age of 9 and 13 drink 2,100mL per day and girls of the same age drink 1,900 mL per day (EFSA, 2010). This recommendation is only a guide because the requirement for fluid intake will vary depending on the amount of fluid consumed within food, the ambient temperature, amount of physical activity, weight and body fat.

The amount of fluid that people consume is not just driven by physiological processes such as thirst but also learned behaviour and social customs. In 2000, a '*Water is Cool*' campaign was launched by ERIC (Education and Resources for Improving Childhood Continence) to encourage schoolchildren to consider that water can be a 'cool' social custom. A number of activities were introduced, including educating schools, parents and teachers about the importance of drinking water and lobbying local government. However, the evidence from Kaushik et al (2007) suggests that it is still not 'cool' to drink water in school. Furthermore, the current Education (Nutritional Standards and Requirements for School Food) (England) Regulations (2007) require only that schools have to provide a supply of drinking water on school premises without specifying where and how often children should have access. Thus, even if drinking water were "cool", it can be difficult for children to consume water during the school day.

Children drink more if they keep water on their desk

Evidence does show that children who have free access to water, on their desk, drink more water than children who have limited access, with water in the classroom but not on desks, or restricted access, with water outside of the classroom (Kaushik et al, 2007). Of the children in schools with free access, 46.5% drank less than the minimum recommended amount compared to 80 and 81% in the other two conditions. Research from Johnston Molloy et al. (2008), in which teachers were interviewed about their attitudes and knowledge of hydration, suggested that teachers were not keen to allow children to have water on their desks at school. Teachers thought that water on the desk may cause disruption in the classroom and an increase in toilet trips. However, although those teachers who did allow water on the desk did initially notice an increase in trips to the toilet this increase did subside quickly. Additionally, teachers did suggest that if they could be convinced that drinking water had a positive effect on classroom performance they would be more likely to consider allowing children to have easier access to drinking water. Recent studies have begun to investigate the question of whether water supplementation improves school performance.

Children perform better when supplemented with water

Results from a number of studies show that children performed significantly better on some cognitive tasks on the occasion on which they have been supplemented with water during the school day, than on occasions on which they had not. Edmonds & Jeffes (2009), Edmonds (2012), found that when children were given additional water their visual attention was significantly better than when they were not given any supplementary water. Visual attention is an important component of learning at school as children require this skill when concentrating on visual stimuli for example when reading and performing written mathematical operations. However, results from Edmonds & Jeffes (2009) showed that water supplementation did not improve the children's performance in fine motor tasks. This is not consistent with evidence from adult dehydration studies which have found that fine motor performance deteriorates in dehydrated adults (see Edmonds, 2012, for review). Fine motor skills are very important at school as research shows that in the course of a school day between 30% and 60% of time is spent using fine motor skills on activities such as handwriting (McHale and Cermak ,1992). Many classroom activities utilise both motor skills and visual attention such as copying text, and in tasks requiring hand eye coordination. Furthermore, there is a correlation between performance in tasks that require motor skills and visual attention, such as throwing and catching, and academic performance (Morales et al., 2011).

As children are in a learning environment for over 6 hours a day, 5 days a week it is important that their cognitive performance is at an optimum level. Therefore, the aim of this study was to determine if consuming water would improve tasks that utilise both fine and gross motor skills, and visual attention. The motor tracking task used in Edmonds & Jeffes (2009) required that the participant followed a track, which is a steady, unmoving target. In the present study a wider range of motor tasks were used.

The Study

A sample of 15 children (8 girls) between the ages of 8 and 9 years old, attending the same primary school were recruited. The children completed a number of tasks, in small groups of 2 to 4, on two occasions at least a week apart. On one occasion the children were supplemented with 250ml bottle of water, from which they could drink as little or as much as they wished and the amount of water consumed was recorded, and on the other occasion the children were not given a bottle of water. On the occasion on which they were not supplemented with a bottle of water, no child asked for a drink. The children were tested 20 minutes after they had begun to drink the water. The conditions were counter-balanced.

Measures

The children completed Visual Analogue Scales to represent levels of thirst and happiness. The two scales each consisted of a line with cartoons at either end depicting the extremes of the scale. The mood ratings were

calculated by measuring from the beginning of the line to the position at which they marked it; a higher score indicated higher levels of thirst and happiness.

The tasks selected that utilise both visual attention and fine motor skills were a letter cancellation task, a '*Ravin Rabbids*' Wii game and ball catching. The letter cancellation task is a paper and pencil task in which the children have to find and cross through a target letter within a grid of distractor letters. The children were given 1 minute to cross through as many targets as possible. Children's scores on this task were calculated by subtracting any errors from the number of correctly identified targets. A higher score indicated better performance.

The '*Ravin Rabbids*' is essentially a "*whack a mole*" game that is performed on the Wii games console. The participants all stood to carry out this task. The children viewed a car full of screaming rabbits. At irregular intervals a rabbit would stand up and the participant was required to bang it on the head by pressing the button and using a downward motion with the Wii handset. The rabbit would then sit back down. The game was played for two minutes and the score was a combination of the number of rabbits hit and the speed in which this was achieved; a higher score indicated better performance.

The ball catching task required the child to catch a ball thrown underarm to them from 2 metres away. If children dropped the ball, they were instructed to pick it up and continue as quickly as possible. The score was the number of times they caught the ball in 2 minutes.

The last task administered predominantly uses gross motor skills. This task, step ups, required the children to step up and down quickly on the bottom step of a set of stairs. The score was the number of step ups completed in a 2 minute period.

Results

In the water supplementation condition, all children consumed some water, drinking an average of 168 ml water (SD = 95ml). The range was from 30 ml to 250 ml and 7 children drank the maximum 250ml water offered. In the no water condition none of the children had a drink.

The scores for all of the tasks were analysed using a t-test to compare the scores that the children self reported and obtained when they were supplemented with a bottle of water with the scores on the occasion on which they were not given any water. The means and standard deviations for each task in each condition along with the results of the statistical analysis are shown in Table 1. Measures that had significantly different results between the water supplementation and no water conditions are shaded.

Table 1: Means and standard deviations, in brackets, for scores in a water supplementation condition and a no water condition

Outcome measures	No water condition	Water supplemented condition	Paired t-tests
	Mean	Mean	
Thirst Scale	.70 (.16)	.31 (.13)	p<.001
Happiness Scale	.67 (.12)	.70 (.14)	ns
Letter Cancellation	128.9 (5.8)	136.4 (5.1)	p<.001
Raving Rabbids	13315.9 (3477.2)	14962.1 (3670.0)	p = .047
Ball Catching	45.6 (6.2)	46.9 (6.0)	ns
Step Ups	110.7 (8.7)	113.0 (9.4)	ns

The children rated themselves as significantly less thirsty on the occasion that they were supplemented with water than on the occasion when they were not. However, levels of self-reported happiness were not sensitive to water supplementation and results were similar on both occasions. In the letter cancellation task and '*Ravin Rabbids*' game the children had significantly higher scores on the occasion when they were supplemented with water compared to the occasion when they were not. However, the ball catching and step up tasks showed no significant effect of water supplementation.

Exploratory analyses were then carried out to assess if the level of thirst or the amount of water drunk correlated with task performance. There was no significant relationship between levels of thirst and task performance, but the

amount of water consumed did correlate with performance on some tasks. In the '*Ravin Rabbids*' task a moderate positive association was found between performance and amount drunk r=.66, p=.008. Additionally, a moderate positive association was found between performance and amount drunk in the ball catching task, r=.69, p=.004. These results initially suggest that this is a dose response effect so that as amount of water consumed gradually increases so do the results for task performance. However, a close look at the data showed that participants either drank less than 100ml of water and achieved lower scores or more than 200ml of water and achieved higher scores.

Discussion

Our results show that performance on tasks requiring both visual attention and fine motor skills were improved by consuming water. When the children were supplemented with water, their scores for the Ravin Rabbids game were higher than when they were not given extra water. The children also performed better in the letter cancellation task when supplemented with water. These results are consistent with Edmonds & Jeffes, (2009), who found a large effect size when investigating the effects of fluid consumption on visual attention and a similarly large effect size was found in this study, with a Cohen's d value of .99.

Furthermore, consuming more than 200ml of water resulted in improved ball catching skills, compared to those who drank less than 200 ml, although this finding must be interpreted with caution. As the participants either drank below 100ml or above 200ml it is not possible to determine how drinking between 100ml to 200ml may have affected task performance. Therefore, it cannot be established whether performance improvement was a bimodal effect of drinking over a specific threshold of water or if the result was a dose response effect of water which could not be clearly observed.

Performance on the step-ups task did not improve in the water supplementation group. This may be because the step-ups task requires the use of larger muscle groups, rather than fine muscle skills and visual attention, which may not be affected by supplementation. However, this finding is not consistent with evidence from the sports literature in which water supplementation has been found to improve physical performance (Edmonds, 2012). Indeed, both stamina and strength have been found to be improved by water consumption in adults. One explanation for this inconsistency with the adult literature might be that the duration of our step ups task was very short, only 2 minutes, and, therefore, resources of stamina or strength were not required to complete the task.

The results from these analyses support the argument that children's performance in tasks that require fine motor skills and visual attention are improved by water supplementation. However, it is not possible to elucidate from this study whether both fine motor skills and visual attention are sensitive to water consumption or whether just one of these skills is improved. Further investigation is already underway to assess these skills separately and in more detail.

Future studies are already taking place in which participants' hydration levels, using biomarkers such as urine osmolality, diet and exercise are recorded before testing. In the current study this information was not collected and so it is not possible to ascertain whether the individual childrens' hydration statuses were similar at baseline and if diet and exercise may have an impact on both the children's hydration status and task performance.

Conclusion

The results from this study suggests that having a drink of water improves children's visual attention and fine motor skills. Thus, it is likely that the positive effects of water supplementation would extend to classroom based activities such as handwriting and copying text. These results add to the growing body of evidence that supports the argument that drinking additional water positively affects children's cognitive performance. This has implications for the availability of water in schools and would suggest that water should be made available in the classroom so that children have regular and easy access to drinking water. Providing easy access to drinking water may be a cheap and simple method of improving performance in the classroom.

References

Barker, M., Benefer, M., Russell, J., Lepicard, E., Constant, F., Hawili, N. and Friedlander, G. (2012, 21-25 April) Hydration deficit after breakfast intake among British schoolchildren. *Experimental Biology*, San Diego, CA, 21-25 April.

Bonnet, F., Lepicard, E.M., Cathrin, L., Letellier, C., Constant, F., Hawili, N. and Friedlander, G. (2012) 'French children start their school day with a hydration deficit'. *Annals of Nutrition and Metabolism*, 60(4), pp. 257-263.

(EFSA), European Food Safety Authority. (2010). Scientific Opinion on Dietary Reference Values for water. EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA). *EFSA Journal,* 8(3), 1459.

Edmonds, C.J. and Burford, D. (2009) 'Should children drink more water? The effects of drinking water on cognition in children'. *Appetite*, 52(3), pp. 776-779.

Edmonds, C.J., & Jeffes, B.(2009). Does having a drink help you think? 6-7-year-old children show improvements in cognitive performance from baseline to test after having a drink of water. *Appetite*, 53(3), 469-472. doi: 10.1016/j.appet.2009.10.002

Edmonds, C.J. (2012). Water, hydration status and cognitive performance. In L. Riby, M. Smith & J. Foster (Eds.), Nutrition and Mental Performance: A Lifespan Perspective. UK: Palgrave Macmillan.

Johnston Molloy, C., Gandy, J., Cunningham, C., & Glennon Slattery, C. (2008). An exploration of factors that influence the regular consumption of water by Irish primary school children. *Journal of Human Nutrition & Dietetics*, 21(5), 512-515.

Kaushik, A., Mullee, M.A., Bryant, T.N., & Hill, C.M. (2007). A study of the association between children's access to drinking water in primary schools and their fluid intake: can water be 'cool' in school? *Child: Care, Health & Development*, 33(4), 409-415. doi: 10.1111/j.1365-2214.2006.00721.x

McHale, K., & Cermak, S.A. (1992). Fine motor activities in elementary school: Preliminary findings and provisional implications for children with fine motor problems. *The American Journal of Occupational Therapy*, 46(10), 898-903.

Morales, J., González, L.M., Guerra, M., Virgili, C., & Unnithan, V. (2011). Physical activity, perceptual-motor performance, and academic learning in 9-to-16-years-old school children. *International Journal of Sport Psychology*, 42(4), 401-415.

Department for Education. (2007). *The Education (Nutritional Standards and Requirements for School Food) (England) Regulations*.