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Impact of Sleep on Attention in Primary School-aged autistic children: Exploratory cross-cultural comparison between Singapore and UK children

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Abstract

Background: There is a growing body of research studying the impact sleep has on attention among typically developing (TD) children, but research is lacking among autistic children.

Aims: The present study aimed to explore, for the first time, differences in (1) attention, (2) sleep parameters among primary school-aged Singaporean autistic children (*N*=26) and Singaporean TD children (*N*=20), and with UK autistic (*N*=11) and UK TD children (*N*=16), and (3) the impact of sleep on attention.

Methods and Procedures: Actigraphy was used to objectively assess sleep, and a Continuous Performance Task was used to measure attentional domains.

Outcomes and Results: There were inconclusive findings indicating that autistic children had poorer sustained attention than TD children. Although autistic children did not display more sleep difficulties than TD children, they showed shorter actual sleep duration (Singapore ASD = 7:00h, UK ASD = 7:35h, $p < .01$) and longer sleep latency (Singapore ASD = 30:15min, UK ASD = 60:00min, $p < .01$) than clinical recommendations. Sleep difficulties were also present among Singaporean and UK TD children. Both TD groups had less actual sleep duration than recommended (Singapore TD = 6:32h, UK TD = 8:07h). Singaporean TD children had sleep efficiency below recommended criterion (78.15%). Sleep impacted attention across all groups, but effects were different for autistic and TD groups.

Conclusions and Implications: The study highlighted the importance for practitioners and carers to adopt a child-centred approach to assessing sleep and attentional difficulties, especially among autistic children due to the high variability in performance within the group. The impact of cultural and school-setting differences on sleep was also raised.

Keywords: Sleep, Attention, Anxiety, Autism, Sleep disorders

What this paper adds:

This paper uses objective actigraphy data and found that autistic children (ASD) in Singapore and UK did not have greater difficulties in initiating and maintaining sleep than TD groups, despite them being commonly reported as main areas of sleep difficulties among autistic individuals. The high variability in sleep parameters and attention performance among autistic children reported in this study highlight the importance of adopting a child-centred approach during assessment. When tailoring sleep interventions, this paper also offers wider systemic consideration of how school settings and culture might influence sleep. In addition, this paper provides preliminary evidence that suggests sleep impacts attention for both typically developing children and autistic children. The study challenges clinicians to examine sleep factors which are often overlooked when supporting children with attentional difficulties. As little is known about the association between sleep and attention in autistic individuals, the paper welcomes future research to replicate the study.

1 Introduction

Sleep difficulties among autistic children such as prolonged sleep initiation, difficulties maintaining sleep and shorter sleep time have been widely reported (e.g. Krakowiak et al., 2008). These sleep difficulties appear to persist throughout the lifespan of autistic individuals, unlike typically developing (TD) children where sleep difficulties tend to diminish with age (Johnson et al., 2007). Current understanding of sleep disturbances among autistic children are primarily based on data from the Western populations, although a small number of sleep studies conducted in Asian cultures similarly showed high prevalence rates of sleep problems in autistic children (e.g. Wang et al., 2016). A recent study also indicated relationships between caregiver and child sleep quality in autistic children (Bin Eid et al., 2022). There is a need for more studies to quantify sleep problems using objective measures since discrepancies between actigraphic data and parent-reports have been reported. The present study is therefore the first to objectively assess sleep characteristics of Singaporean autistic and TD children and compare them to UK TD and autistic children, alongside their attentional profiles.

The association between sleep and attention among autistic children has not been extensively examined, nor well understood. Studies with TD children and adults, and children with Attention Deficit Hyperactivity Disorder (ADHD) provide evidence that sleep impacts sustained attention (Ashworth et al., 2015). Sleep deprivation can cause general slowing of reaction times, higher incidence of lapsing and enhances the time-on-task effect. Adopting Karmiloff-Smith's connectionist model of development (Karmiloff-Smith, 2013), the current study takes the view that sleep difficulties among autistic children can interact with cognitive processes and introduce environmental vulnerabilities, leading to or exacerbating sustained attention deficits among autistic children.

Cultural differences also affect prevalence rates, etiologic and contributing factors towards sleep problems. Preliminary studies revealed that TD infants (aged 0 to 3 years) in predominantly-Asian countries have later bedtime, shorter sleep duration, and more parent-reported sleep problems than those in predominantly-Caucasian countries (Sadeh et al., 2011). The only published cross-cultural study with autistic children, revealed that Chinese participants had more severe sleep onset delay and sleep-disordered breathing than Americans (Wang et al., 2016).

1.1 Current study

As little is known about the impact of sleep among autistic children, the aim of this study was to investigate sleep and its associated impact on attention in this population, using actigraphy and a computerised Continuous Performance Task (CPT). The present study took an explorative approach and compared among Singaporean and UK autistic and TD children: (1) attentional performance, (2) habitual sleep parameters, and (3) investigated the impact of sleep on attention. (4) Developmental trajectories on the attention scores against chronological and mental age were investigated. It was hypothesised that autistic children would have poorer attentional skills and more sleep difficulties compared to TD children; and that poor sleep parameters would contribute to poorer attention performance. Cross-cultural differences in sleep and attention parameters between Singaporean and UK children were also postulated. There is a lack of cross-cultural sleep research with children, and even less with autistic children. Few studies have also compared sleep patterns in children between Eastern and Western cultures where societal contexts such as work and school affect sleep patterns differently. For example, academic performance is a top priority for families particularly in Asian countries and young people are engaged in extracurricular studies in favour of sleep, leading to delayed bedtime or reduced sleep duration (Huan et al., 2008). A cross-cultural comparison in sleep data could uncover underlying cultural differences in sleep habits that impact contributing factors towards sleep problems.

2 Methods

Participants and procedure

29 autistic children and 21 TD children aged 6 to 13 years were recruited in Singapore. Singaporean autistic children were grouped based on whether they attended mainstream (ASD-M; *n* = 12) or specialist schools (ASD-S; *n* = 14). 11 autistic children and 16 TD children aged 6 to 12 years were recruited in UK. Due to the small sample size, the UK ASD-M and ASD-S group was analysed together.

All parents confirmed that children had received a formal ASD (DSM-V) diagnosis prior to the study. This study was granted ethical approval from the University College London Ethics Committee. All parents and children (when possible) gave written consent and verbal assent prior to participation. Parents confirmed that all children were not on medication for sleep problems, had no health problems, comorbid disorders, psychiatric, or current medical conditions. Details of the final sample and procedure can be found in the Supplementary Materials.

Measures

Actigraphy. Sleep patterns were measured objectively and non-intrusively using actigraphy (see Supplementary Material for more details). Children were requested to wear the MotionWatch8 (CamNTech, Cambridge, UK) on the non-dominant wrist from Sunday night to Friday morning. Data were analysed in 30-sec epochs using MotionWare software (CamNTech, Cambridge, UK).

Raven's Colored Progressive Matrices (RCPM). The RCPM (Raven et al., 1995) is an extensively-used cognitive assessment of fluid intelligence among children aged three to 12 years to determine their intellectual capacity relative to other people of the same age. RCPM was chosen because it is a non-verbal test, comparatively short to administer and engaging. This made it suitable to measure mental age (MA) among autistic children who may have limited language comprehension and expression. Additionally, a measure of MA is necessary when researching with developmental disorder groups whose mental age is often discordant with their chronological age (CA) (Ashworth et al., 2015) and the RCPM has been commonly used to match autistic children with TD children.

Continuous Performance Attention Task (CPT). A CPT suitable for autistic children, which assesses different components of sustained attention – inattention, impulsivity, processing speed, inhibition and inconsistency in response was used. The current CPT was adapted from previous studies involving children with developmental disorders (Ashworth et al., 2015; Steele et al., 2012). DMDX software (Forster & Forster, 2003) was used to present stimuli and accurately record RTs. The detailed procedure can be found in the Supplementary Materials.

Percentage of correct hits, percentage of commission error (incorrect hits), RT hits, RT errors and variability of correct RT hits (intra-subject standard deviation) were recorded. These measures corresponded to different aspects of sustained attention: inattention (percentage of correct hits), impulsivity (percentage of commission errors), processing speed (RT hits), inhibition (RT errors) and inconsistency in responses (RT variability).

Questionnaire. Parents completed an online questionnaire which gathered information regarding children's gender, age, ethnicity, parent's education levels, child's sleep, health, media use habits and medical background.

Results

CPT Performance

One-way between group ANOVAs were computed to investigate group differences on CPT performance (Table 1). When CA and MA were controlled using ANCOVA models (Table 2), the Singaporean ASD-S group had a lower percentage of correct hits and higher percentage of commission errors than Singaporean ASD-M, Singaporean TD children and UK TD children too. Singaporean ASD-S children had the highest percentage of commission errors, followed by Singaporean ASD-M children, who had higher percentage of commission errors than Singaporean TD children but not UK TD children. The UK ASD children had higher RT errors than Singaporean TD and ASD-M children. The UK TD children had higher RT errors than Singaporean TD children. For RT variability, Singaporean ASD-S children showed the highest RT variability, followed by UK ASD children who had higher RT variability than Singaporean TD and UK TD children. Singaporean ASD-M children had lower

RT variability than Singaporean TD and UK TD children, but the difference was not significant.

Table 1 *Mean scores (SD) and group differences using ANOVA for selected CPT performance variables not controlling for school session (CA and MA not controlled)*

	S'pore ASD-S *(N=14)*	S'pore ASD-M *(N=12)*	S'pore TD *(N=20)*	UK ASD *(N=11)*	UK TD (N=16)	CA and MA not controlled F	CA and MA not controlled η^2
Correct hits (%)	74.64 (19.66)	97.92 (3.34)	97.25 (6.17)	82.27 (25.73)	97.81 (3.64)	**8.95****	.34 [a,b,d,g,h]
Commi-ssion errors (%)	20.18 (20.61)	2.60 (1.80)	1.06 (1.36)	9.43 (12.62)	1.72 (2.28)	**9.01****	.35 [a,b,d]
RT hits (ms)	567.32 (92.93)	515.14 (98.60)	505.70 (90.21)	610.19 (257.76)	677.24 (288.55)	**2.38**	.28
RT errors (ms)	501.44 (129.27)	410.44 (125.09)	394.79 (94.55)	620.73 (158.16)	526.95 (94.97)	**6.17****	.15 [h,j]

Note: significant effects in **bold**. **p*<.05, ***p*<.01[a]

[a] = Significant difference between Singapore ASD-S and Singapore ASD-M

[b] = Significant difference between Singapore ASD-S and Singapore TD

[c] = Significant difference between Singapore ASD-M and Singapore TD

[d] = Significant difference between Singapore ASD-S and UK TD

[e] = Significant difference between Singapore ASD-M and UK TD

[f] = Significant difference between Singapore TD and UK TD

[g] = Significant difference between UK ASD and UK TD

[h] = Significant difference between Singapore TD and UK ASD

[i] = Significant difference between Singapore ASD-S and UK ASD

[j] = Significant difference between Singapore ASD-M and UK ASD

Table 2 *Mean scores (SD) and group differences using ANOVA for CPT performance not controlling for school session (CA and MA are controlled)*

	S'pore ASD-S *(N=14)*	S'pore ASD-M *(N=12)*	S'pore TD *(N=20)*	UK ASD *(N=11)*	UK TD (N=16)	CA and MA controlled F	η²
Correct hits (%)	74.64 (19.66)	97.92 (3.34)	97.25 (6.17)	82.27 (25.73)	97.81 (3.64)	**3.62****	.18 [d]
Commi-ssion errors (%)	20.18 (20.61)	2.60 (1.80)	1.06 (1.36)	9.43 (12.62)	1.72 (2.28)	**3.67****	.18 [d]
RT hits (ms)	567.32 (92.93)	515.14 (98.60)	505.70 (90.21)	610.19 (257.76)	677.24 (288.55)	**2.17**	.12
RT errors (ms)	501.44 (129.27)	410.44 (125.09)	394.79 (94.55)	620.73 (158.16)	526.95 (94.97)	**4.61****	.26 [h,j]

Note: significant effects in **bold**. *p<.05, **p<.01[a]

[a] = Significant difference between Singapore ASD-S and Singapore ASD-M

[b] = Significant difference between Singapore ASD-S and Singapore TD

[c] = Significant difference between Singapore ASD-M and Singapore TD

[d] = Significant difference between Singapore ASD-S and UK TD

[e] = Significant difference between Singapore ASD-M and UK TD

[f] = Significant difference between Singapore TD and UK TD

[g] = Significant difference between UK ASD and UK TD

[h] = Significant difference between Singapore TD and UK ASD

[i] = Significant difference between Singapore ASD-S and UK ASD

[j] = Significant difference between Singapore ASD-M and UK ASD

Developmental Effects on CPT

Linear Regression was used to investigate CA and MA related changes in CPT variables (see Supplementary Materials). CA was not significantly associated with any CPT variables for any group. MA was not significantly associated with CPT performance for both Singapore and UK TD children but was significantly correlated to RT variability for UK ASD children. In the ASD-S group, increased MA predicted higher percentage of correct hits. In the ASD-M group increased MA predicted longer RT hits.

Actigraphy

One-way between-group ANOVAs were computed to investigate group differences on actigraphy sleep parameters across both the Singapore and UK sample (see Supplementary Materials). Sleep efficiency, sleep latency and mean night-waking duration showed significant group differences in the one-way ANOVA test. However, when unequal variance was corrected for, post-hoc analysis did not indicate differences.

Association between sleep and attention

Hierarchical multiple regression was used to examine the association between sleep parameters and CPT performance (see Supplementary Material for details).

Singapore sample. For the autistic group**,** both longer sleep duration (R^2_{change}=.32, $F_{change}(1,17)=8.21$, $p<.05$) and better sleep quality (R^2_{change}=.34, $F_{change}(3, 14)=5.70$, $p<.01$) predicted longer RT errors. Sleep duration and quality were unable to predict significant variance in other CPT variables. However, other sleep variables were able to predict the remaining CPT variables, except RT variability. Further, in the autistic group, later bedtime

(R^2_{change}=.11, F_{change}(1,16)=7.62, *p*<.05) predicted lower percentage of correct hits. Higher fragmentation index (R^2_{change}=.15, F_{change}(1,16)=6.72, *p*<.05) predicted lower percentage of commission errors. Higher fragmentation index (R^2_{change}=.13, F_{change}(1,16)=5.43, *p*<.05) and shorter time in bed (R^2_{change}=.10, F_{change}(1,15)=5.25, *p*<.05) predicted longer RT hits.

For the TD group, sleep duration and quality did not predict significant variance on any CPT variable. However, later bedtime (R^2_{change}=.32, F_{change}(1,11)=9.06, *p*<.05) predicted lower percentage of correct hits. Later get-up time (R^2_{change}=.31, F_{change}(1,11)=20.31, *p*<.01) predicted higher percentage of commission errors. No sleep variables were able to predict RT hits, RT errors and RT variability for the TD group.

UK sample. For UK TD children, higher actual sleep percentage predicted faster RT hits (R^2_{change}=.62, F_{change}(1,8)=38.19, *p*<.001) and faster RT errors (R^2_{change}=.19, F_{change}(1,7)=8.32, *p*<.05). Longer assumed sleep also predicted faster RT errors (R^2_{change}=.28, F_{change}(1,8)=6.62, *p*<.05) among UK TD children.

Among UK ASD children, better sleep quality predicted higher percentage of correct hits (R^2_{change}=.57, F_{change}(3,4)=11.27, *p*<.05) and faster RT hits (R^2_{change}=.61, F_{change}(3,4)=52.71, *p*<.001).

3 Discussion

Attention

Findings from the CPT partly support previous research that autistic children have difficulties with sustained attention. ASD-S children displayed higher levels of impulsivity (higher percentage of commission errors) and were more inconsistent in responses (higher RT variability) than Singaporean TD children after CA and MA were controlled for. However, the UK ASD group did not differ from the UK TD group across CPT performance, and only showed higher RT errors compared with Singaporean TD and ASD-M groups.

Attention performance among Singaporean autistic children was associated with cognitive development (MA), rather than age-related development, especially in inattention and processing speed. It is probable that for autistic children, variations in cognitive development and neural pathways account for greater explanatory power in understanding their sustained attention performance, than age-related developmental processes (Allen & Courchesne, 2001). The lack of such finding among the UK ASD sample in this study could be due to the narrow range of MA within the group.

Sleep

Sleep patterns among autistic children. The cross-cultural investigation revealed that the sleep difficulties frequently reported in literature around sleep latency and maintenance of sleep (e.g. Souders et al., 2009) were not consistently found among autistic children in both Singapore and UK. Across all autistic children, their mean sleep efficiency fell short of the normal sleep efficiency criterion of 80%. The Singaporean ASD-S and the UK-ASD group had a mean sleep latency longer than 30 minutes, which is the cut-off used by Children's Hospital of Philadelphia for defining long sleep latency (Souders et al., 2009). A plausible explanation of the absence of a delayed sleep onset among Singaporean ASD-M children could be their shorter sleep duration compared to UK ASD children. Sleep restriction and deprivation increase sleep propensity, indicated by a faster sleep onset latency (Whittall et al., 2018).

Across all autistic groups, there was similar propensity in children's time in bed despite differences in culture, MA and school start times. Although Singaporean ASD-M children had earlier bedtime than Singaporean ASD-S children, they also had a later get-up time. ASD-M children had shorter actual sleep time than UK ASD children.

Sleep parameters between Singapore and UK TD children. There was no significant group difference in bedtime indicating that Singaporean TD children (*M*=9:50pm, *SD*=0:53) had similar bedtime as UK TD children (*M*=9:17pm, *SD*=0:33); but, their get-up times (*M*=6:17am, *SD*=0:25) were on average about one hour earlier than UK TD children (*M*=7:10am, *SD*=0:46). Singapore TD children slept only an average of 6:32 hours while UK TD children slept an average of 8 hours, which are lower than the recommended nine to eleven sleep hours for school-aged children by the National Sleep Foundation (Hirshkowitz et al., 2015). Singaporean TD children mean sleep efficiency was below the normal sleep efficiency criterion of 80% whereas that of UK TD children was above. These findings are consistent with existing literature that found that children from Asian countries not only sleep less than children from other countries like Europe or United States, but also report needing less sleep (Matricciani et al., 2013).

We considered social factors that could impact between-group differences in sleep duration that impacted get-up time in our TD primary school-aged sample. School start time places a considerable social constraint on children's sleep duration, and it has been widely predicted to affect sleep duration across countries (Liu et al., 2005). Typically, mainstream primary schools start an hour earlier in Singapore (7:30am) than in UK (8:30am), and hence has a knock-on effect on wake time. Though the study needs to be replicated in a primary school setting, there is preliminary evidence to suggest that within a Singaporean context, school start times have an impact on sleep duration by influencing get-up time.

Association between Sleep and Attention

The current findings suggest that the impact of sleep on attention is different for autistic and TD children and affected by cross-cultural factors. Later bedtime was associated with higher inattention in Singapore TD children. Similar findings were reported by other research, where shorter sleep duration affected higher inattention among TD children (Lo et al., 2016). However, for Singaporean autistic children, bedtime had the opposite effect on inattention. Glickman (2010) suggested that autistic children could have delayed sleep-phase syndrome, preferring later sleep onset and wake times than those dictated by societal norms. Hence, earlier bedtimes may not be as helpful for autistic children. For UK autistic children, inattention was predicted by sleep quality, and for UK TD children, no known sleep parameters were found to significantly impact inattention. Inconsistency in response was not associated with sleep parameters across all children.

While sleep parameters were found to have a significant impact on attention for both autistic and TD children, their explained variance on attentional variables is still relatively inconsistent. The highest explained variance by a single variable was 62% for actual sleep percentage predicting RT hits for UK TD children, and the lowest was 10% for time in bed predicting

RT hits among Singapore ASD children. This high variability could reflect that sleep may be impacting on mediating factors that could influence attention, rather than directly. Future studies should build on our work by examining the impact of sleep on these mediating factors such as motivation, anxiety and sensory processing.

Limitations

Although the study reports undiscovered group differences in how sleep affects attention between autistic and TD children, the small sample size in the present study limits its generalizability. However, the comparison of objective measurements of multiple sleep parameters and attention has not been previously done and the present study contributes novel data in understanding the relationship between sleep and attention. Considerations include heterogeneity in phenotypic profiles expressed by autistic children and possible selection bias in the autistic group (unknown existing treatment for sleep problems was not known, possible exclusion of tactile sensitive autistic children due to the use of the actiwatch). Future studies and replication studies would benefit from more participants to add power, validate cross-cultural differences and allow more detailed analyses on a more homogenous group within the autistic population. Longitudinal studies can also help to better elucidate cross-cultural differences in sleep patterns across the developmental trajectory across groups.

4 Conclusion

In conclusion, the study highlighted the importance of sleep and its impact on day-time attention. Sleep has received very little attention in clinical practice where intervention guidelines in behavioural management of autistic individuals often do not sufficiently account for sleep, despite the profound and extensive impact sleep can have on cognition. The present study sought to challenge professionals to rightfully consider the important role of sleep on cognitive processes, specifically attention, as well as cross-cultural factors influencing sleep patterns in children.

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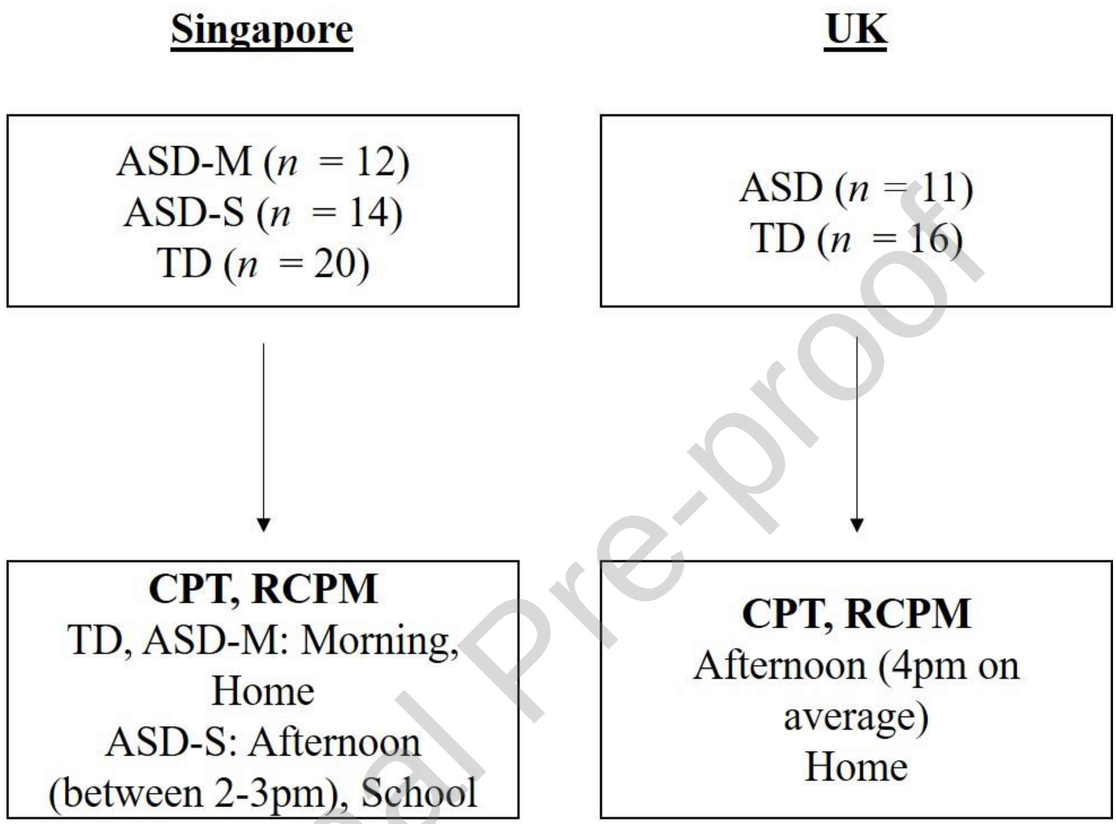

Figure 1. Procedure for the Singapore and UK sample

Figure 2. Stimuli used in CPT

Highlights

- Autistic children presented variability in sustained attention performance.
- Longer sleep latency and lower sleep efficiency were present among Singaporean and UK autistic children.
- Singaporean and UK typically developing children had short sleep duration. Singaporean typically developing children also showed poor sleep efficiency.
- Sleep impacts attention differently across autistic and TD groups, and across culture.