Brief Report

Effect of a naturalistic prospective memory-related task on the cortisol awakening response in young children

Damaris Bäumler a, Matthias Kliegel b, Clemens Kirschbaum a, Robert Miller a, Nina Alexander a, Tobias Stalder a,∗

a Technische Universität Dresden, Department of Psychology, Dresden, Germany
b University of Geneva, Department of Psychology, Geneva, Switzerland

A R T I C L E   I N F O

Article history:
Received 14 March 2014
Accepted 8 August 2014
Available online 19 August 2014

Keywords:
Cortisol awakening response
Prospective memory
Children
Experimental
Anticipation

A B S T R A C T

Activation of prospective memory (PM) representations following awakening has been proposed to modulate expression of the cortisol awakening response (CAR). However, experimental testing of this hypothesis is still missing. This study examined the effect of a naturalistic PM-related manipulation on the CAR in a sample of 35 preschool-aged children. The CAR was assessed on two study days (0 and 30 min post-awakening) using objective verification of awakening and sampling times. Children had to remember to perform a naturalistic PM-related task (reminding their parents about a gift) on the experimental day while there was no intervention on the control day (counterbalanced order). Results revealed an increased CAR on the experimental day (mean ± SD increase: 9.97 ± 7.05 nmol/L) compared to the control day (mean ± SD increase: 5.45 ± 8.14 nmol/L; p = .022). Our findings concur with the notion that expression of the CAR is modulated by post-awakening anticipatory processes involving activation of PM representations.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The cortisol awakening response (CAR), the increase in cortisol levels following morning awakening, is frequently measured in Biological Psychology research. However, the physiological role of the CAR is still largely unknown (Clow, Hucklebridge, Stalder, Evans, & Thorn, 2010). A current hypothesis holds that the CAR helps to prepare the organism for the demands of the upcoming day (e.g., Fries, Dettenborn, & Kirschbaum, 2009). As part of this, cognitive processes related to anticipation of the day ahead have been proposed to modulate day-to-day variability in the CAR (Wilhelm, Born, Kudielka, Schlotz, & Wust, 2007). One aspect of cognitive functioning relevant to this is prospective memory (PM), i.e., the ability to remember to perform an intended action after a certain delay (see Fries et al., 2009). Consistently, an increased CAR has been shown on days with assumed higher PM-load, e.g., days with an elevated burden or workload (see Law, Hucklebridge, Thorn, Evans, & Clow, 2013). Further, regulation of PM and the CAR rely on shared hippocampal and prefrontal structures (Schacter, Addis, & Buckner, 2007; Fries et al., 2009). Finally, we have recently shown a positive association between a behavioural measure of general PM ability and the CAR in young children (Bäumler et al., 2014).

The above data concur with the notion that activation of PM representations after awakening influences the expression of the CAR. However, experimental examination of this proposition is still outstanding. The current study tested the hypothesis that remembering to perform a naturalistic PM-related task after awakening results in an increased CAR compared to a control day without PM task. To allow for a clearer manipulation of PM, we examined young children who are able to perform PM tasks (Kliegel & Jäger, 2007) and who were expected to engage in less unwanted speculation about the experimental background of the study compared to adults. Further, we expected less anticipation interference issues with the PM task in children who normally face less competing obligations than adults. As in our previous research, we applied rigorous CAR adherence control using objective measures of awakening- and sampling times (Bäumler, Kirschbaum, Kliegel, Alexander, & Stalder, 2013; Stalder et al., 2013).
2. Methods

2.1. Participants

Participants from a previous study (Bäumer et al., 2013) were re-invited to participate in the current research. Mothers of children in good mental and physical health, not taking any medication were contacted. Data of 35 preschoolers (15 female), aged three to six years (range: 37–83 months; mean ± SD age: 61.07 ± 13.45 months) were available for analyses. Out of 57 initially recruited children, 22 were excluded because of insufficient saliva for cortisol analyses (n = 11) or failure to perform the naturalistic PM task correctly (n = 11). Written informed consent was provided by one parent. The study protocol was approved by the local ethics committee and conducted in accordance with the Declaration of Helsinki. Each parent–child pair received 10 Euro and a small gift for the child.

2.2. Design, procedure and saliva sampling

Saliva sampling was carried out by children’s parents on two non-consecutive study days within a one week period. Children had to remember to perform the PM task (described below) over the post-awakening period of one day while there was no intervention on the other day (counterbalanced). On each day, saliva sampling was carried out on awakening and 30 min post-awakening using Eye spear collection devices (bvi Beaver Visitec, Waltham, USA). Data collection took place mainly during the winter months. Parents were told to avoid brushing children’s teeth prior to saliva sampling and to withhold food and drinks 2 h prior to awakening and until the end of the saliva sampling. Saliva samples were stored at −20 °C and cortisol concentrations were analyzed via a commercially available immunoassay (IBL, Hamburg, Germany). Children’s sleep the night prior to saliva sampling was assessed using Actiwatch 2 devices (AW2; Philips Respironics, Murryville, PA). Children’s awakening and sampling times were verified through AW2-based actigraphy and through MEMS 6 TrackCap monitoring containers (Aardex Ltd., Switzerland), respectively. The importance of strict adherence to protocol was emphasized and parents filled in a short diary to record performance of the PM task, children’s bed-, awakening- and sampling times or any difficulties with sample collection.

2.3. Naturalistic prospective memory task

Parents were provided with the order of study days (regular vs. PM day). They were instructed to tell their child on the evening before the PM day that he/she would get a gift the next morning but that, in order to get the gift, he/she would have to remind the parent about the gift right after awakening. Thus, the PM task required the child to remember to perform an intended action of personal relevance with assumed positive valence. After completion of saliva sampling on the PM day, the child received the gift.

2.4. Data exclusion and statistical analysis

Study days were excluded from analyses if a difference >15 min was found between (i) self-reported awakening times and AW2-verified awakening times and/or between (ii) pre-specified sampling times (AW2 data) and MEMS-verified sampling times (as in Stalder et al., 2013). This resulted in a total of 60 compliant study days from 35 participants being available for analyses. A Bayesian mixed-effects model1 was employed to predict the effect of the PM manipulation (PM) on post-awakening cortisol changes (ΔS = S2 − S1), i.e., the CAR. In an extended model,2 cortisol levels on awakening (S1) were also included as a predictor (Clow et al., 2010). ΔS scores were normally distributed (Shapiro–Wilks). All p-values refer to two-sided tests.

3. Results

The modelling of cortisol changes over the post-awakening period revealed a main effect of sampling time [z(β1) = 4.27, p < .001] demonstrating a significant CAR across study days. A post-awakening cortisol increase exceeding 1.5 nmol/L (Miller, Plessow, Kirschbaum, & Stalder, 2013) was found on 75% of study days and 31 (out of 35) children exhibited such an increase on at least one study day. The PM manipulation was found to significantly predict the CAR [z(β2) = 2.27, p = .022; see Fig. 1]. In the extended model, both PM manipulation [z(β3) = 2.02, p = .044] and S1 [z(β4) = −2.83, p = .005] significantly predicted the CAR. Descriptively, the mean (±SD) increase in cortisol levels from 0 to 30 min post-awakening (ΔS) was 9.97 (±7.05) nmol/L on the PM day and 5.45 (±8.14) nmol/L on the regular day. Children’s sleep (awakening time, sleep duration, wake after sleep onset – an index for sleep fragmentation) did not differ between study days (all ps ≥ .26).

4. Discussion

To the best of our knowledge, this is the first study to experimentally investigate the effect of a naturalistic PM-related manipulation on the CAR. Our findings revealed a more pronounced CAR on the experimental day compared to the control day. These data complement earlier quasi-experimental evidence showing increased CARs on days with assumed higher PM-load (Schlotz, Hellhammer, Schulz, & Stone, 2004; Stalder, Evans, Hucklebridge, & Clow, 2010). This further supports the notion that regulation of the CAR is linked to cognitive ‘booting-like’ processes following awakening, involving the activation of PM representations (Fries et al., 2009; Wilhelm et al., 2007).

The current findings suggest that day-to-day differences in post-awakening PM activation play a role in modulating the expression of the CAR. This concurs with our recent cross-sectional data showing young children’s general ability to perform a PM task to be positively related to their CAR (Bäumer et al., 2014). On the other hand, we have recently shown that an adult-like CAR is present from as early as two months of age (i.e., prior to PM development) which makes it unlikely that post-awakening PM activation is a necessary requirement for expression of the CAR (Stalder et al., 2013). In aiming to reconcile these data, it can first be assumed that the CAR fulfills some fundamental physiological function (e.g., daily energy mobilization, Adam, Hawkley, Kudielka, & Cacioppo, 2006) as indicated by its early ontogeny. This function may initially be executed at set level; however, as PM abilities develop, it may become more adaptive to flexibly adjust this function in line with anticipated demands for a particular day. Our data concur with the notion that PM-related processes following awakening play a role in this process (Fries et al., 2009).

An interesting aspect of the current study is that the employed task involved remembering an event of assumed positive valence (i.e., receiving a gift). Our findings thus speak against the view that a marked CAR is a principal correlate of adverse, stress-related constructs, as indicated by some between-subject research (see Chida

---

1 ΔS = β0 + βX × PM, with i denoting the respective child.
2 ΔS = β0 + βX × PM + βS × S1, with i denoting the respective child.

---

Fig. 1. Children’s mean (±standard error) post-awakening cortisol levels on the prospective memory and the regular study day (note that statistical analyses were conducted using 0–30 min cortisol change scores).
& Steptoe, 2009), but that the CAR fulfils an adaptive role in normal everyday physiology (Clow et al., 2010). On the other hand, the use of a positively valenced task in the present study means that effects of PM cannot be clearly distinguished from those of reward anticipation, i.e. positive expectation/excitement about the gift. This constitutes a limitation to be addressed in future research. Other limitations also include the reliance on only two post-awakening saliva samples to assess the CAR and the relatively small sample size.

The current study provides first preliminary evidence for the modifiability of the CAR by a naturalistic PM-related task of positive valence in preschool aged children. Future research may examine whether this effect can be further increased, e.g. by changing characteristics of the remembered PM material, and whether the current findings extend to adult populations.

Conflict of interest

The authors report no conflicts of interest.

References


