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The relation of the cortisol awakening response and prospective memory functioning in young children

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ABSTRACT

Recent research suggests that the cortisol awakening response (CAR) is linked to cognitive functions depending on hippocampal and frontal cortex circuits and may possibly be modulated by prospective memory (PM). However, the link between the CAR and PM abilities has not been investigated so far. Addressing this open issue, we report data from 97 children aged 37–87 months. Salivary cortisol levels were assessed 0 and 30 min post-awakening over three study days. Thereby a valid CAR measurement was ensured by using objective measures of awakening and sampling times. A game-like task served as behavioral measure of PM performance. Bayesian analysis revealed a positive association between children's PM performance and the CAR, with better PM performance being related to a greater CAR. This association persisted after controlling for age. Overall, the current finding supports the prediction that PM functioning may be linked to the CAR, possibly as both the CAR and PM rely on a common neurophysiological basis.

1. Introduction

The cortisol awakening response (CAR) is a neuroendocrine response to awakening and denotes the sharp increase of cortisol levels peaking within 30–45 min after awakening (e.g. Pruessner et al., 1997; Wilhelm, Born, Kudielka, Schlotz, & Wust, 2007). The CAR is a frequently used measure in psychoneuroendocrinological research and has been linked to a number of demographic, psychosocial and health-related factors (Chida & Steptoe, 2009; Fries, Dettenborn, & Kirschbaum, 2009). Despite these findings, it is still an open question why individuals show this increased cortisol release to awakening (e.g. Fries et al., 2009; Clow, Hucklebridge, & Thorn, 2010). It has been suggested that the CAR prepares the body and mind for the daily challenges anticipated during awakening (Clow, Hucklebridge, & Thorn, 2010; Fries et al., 2009; Wilhelm et al., 2007). The activation of specific intentions concerning the demands of the upcoming day is believed to modulate the magnitude of the CAR. In this respect, researchers have suggested that the CAR and processes of prospective memory (PM) might be linked (e.g. Fries et al., 2009).

Prospective memory refers to the ability to remember to perform an intended action after a certain delay (Ellis, 1996) including the formation of an intention by anticipating upcoming demands of everyday life. One example for prospective memory is to remember to hand over a message to a friend or to take ones medication at a specific time point. PM is contrasted to retrospective memory, i.e. processes of remembering information from the past (Brandimonte, Einstein, & McDaniel, 1996; Kliegel, McDaniel, & Einstein, 2008).

From multiple perspectives, there is support for the assumption that the CAR is possibly linked to prospective memory functioning. First, the magnitude of the CAR seems to be influenced by the anticipated daily demands of the upcoming day in adulthood (see Clow, Hucklebridge, & Thorn, 2010; Fries et al., 2009 for review). For example an increased CAR was reported for individuals facing elevated burden or work overload (e.g. Mikolajczak et al., 2010; Schlotz, Hellhammer, Schulz, & Stone, 2004; Steptoe, Cropley, Griffith, & Kirschbaum, 2000). In another study the CAR has been found to be positively associated with the study-day anticipations of the level of obligations (Stalder, Evans, Hucklebridge, & Clow, 2010).

Second, there is a growing body of evidence for a link between the magnitude of the CAR and cognitive functions in older adults and toddlers (Almela, van der Meij, Hidalgo, Villada, & Salvador, 2012; Evans et al., 2011; Evans, Hucklebridge, Loveday, & Clow,

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2012; Saridjan et al., 2013). Specifically, it has been suggested that the magnitude of the CAR may be a biomarker of brain functioning in elderly (Evans et al., 2012) and a risk marker of delay in cognitive functioning in toddlers (Saridjan et al., 2013). Particularly cognitive functions that depend on hippocampal and frontal cortex circuits have been found to be associated with the magnitude of the CAR (e.g. Almela et al., 2012; Evans et al., 2011, 2012). This finding is especially interesting with regard to the link between the CAR and PM, as PM involves both frontal (underlying the prospective component of PM responsible for detecting the target cues and self-initiating the execution of the delayed intention) and hippocampal (underlying the retrospective component of PM associated with storing and retrieving the intention content) networks (e.g. Gordon, Shelton, Bugg, McDaniel, & Head, 2011; McDaniel & Einstein, 2011; McDaniel, Glisky, Guynn, & Routhieaux, 1999; West, 2011). During preschool-age frontal cortex circuits and related cognitive functions, such as event-based PM develop substantially showing high interindividual variability (see e.g. Kliegel, Brandenberger, & Aberle, 2008; Kliegel & Jäger, 2007; Kvavilashvili, Kyle, & Messer, 2008; Tsujimoto, 2008; Wang, Kliegel, Liu, & Yang, 2008). At the same time the CAR has recently been shown to be stable observable in preschool-aged children (see e.g. reference values provided in Bäumler, Kirschbaum, Kliegel, Alexander, & Stalder, 2013). For these two reasons, it seems particularly promising to examine the link between the CAR and PM during preschool age, analog to the rationale of Evans et al. (2012), who studied the link between the CAR and executive functions in elderly an age-range with a high naturally occurring variance in executive functioning.

Taken together, the current study aims to investigate the association between PM functioning and the CAR in healthy young children, a population that seems particularly well suited, for the above mentioned reason, to explore this relationship. For valid investigation of the CAR objective measures were used to verify children's awakening times (via wrist actigraphy) and sampling times (via electronic monitoring containers). The CAR was assessed repeatedly over three study days within 14 days. In the same period PM performance was tested applying a standard paradigm for testing PM in children.

2. Methods

2.1. Participants

A total of 97 children (47 females) were recruited from the greater Dresden area at local kindergartens, pediatric practices or parent–child courses. This was a subsample of our prior work on the physiology of the CAR (Bäumler et al., 2013). Children were aged 37–87 months (mean ± SD: 59.87 ± 13.01 months). In detail the sample consisted of 23 three-year-old (mean ± SD: 43.52 ± 3.42 months), 27 four-year-old (mean ± SD: 54.37 ± 3.08 months), 25 five-year-old children (mean ± SD: 64.60 ± 3.66 months) and 22 children aged six years and older (mean ± SD: 78.32 ± 4.36 months). All children were in good mental and physical health and not taking any medication. Only children who provided enough saliva on at least one study day and took part in the cognitive testing session (see below) were included. Written informed consent was gathered from at least one parent. The study protocol was approved by the local ethics committee and carried out in accordance with the declaration of Helsinki. Each parent–child pair received 20 Euro for collecting saliva over three days and additionally 10 Euro for participating in the cognitive testing session.

2.2. Design and procedure

Study design and procedure regarding saliva sampling were identical to the approach reported in Stalder et al. (2013). In brief, parents were familiarized with the study procedure and trained on the collection of saliva sampling in children. The strict adherence to the study protocol, when collecting saliva samples from their children on three days within a period of two weeks, was specially emphasized. Furthermore, parents were asked to fill in a short sampling protocol, recording children's bed- and awakening times, sampling times and any difficulties with the sample collection. Saliva samples were stored in parents' home freezer and delivered to the laboratory after the last sampling day. PM testing was carried out in the same period of time and took place either in our laboratory or at the children's home. The experimenter paid careful attention to ensure, that testing conditions were comparable between the laboratory and children's home. Each child was tested individually according to a standardized manual. Parents were allowed to stay in the testing room, but were asked to sit out of direct sight of their child (e.g. behind the child).

2.3. Saliva sampling in young children and adherence control

As described in detail in Stalder et al. (2013) parents were asked to gently wake up their child, to reduce the risk of a missed first morning sample due to prior awakening, and to collect two saliva samples, the first immediately upon awakening and the second 30 min thereafter. Saliva sampling had to be postponed until the following day if the child had woken up spontaneously prior to parents' arrival. Additionally parents were told to withhold food and drink 2 h prior awakening and to not brush their child's teeth prior to sampling, to avoid contamination of samples (Egliston, McMahon, & Austin, 2007). Saliva samples were collected with small sponge-like collection devices (bvi Beaver Visitec, Waltham, USA) which were ideally suited for children (de Weerth, Jansen, Vos, Maitimu, & Lentjes, 2007). Parents were asked to place the sponge-like devise under the child's tongue until it was swelled many times over. Saliva samplings were stored at −20 °C until assaying. Salivary cortisol concentrations were analyzed via a commercially available chemiluminiscence immunoassay (CLIA, IBL, Hamburg, Germany). Motility readings from Actiwatch 2 devices (AW2; Phillips Respironics, Murryville, PA) were used to verify children's awakening times. Sampling times were verified via electronic monitoring containers (MEMS 6 TrackCap; Aardex Ltd., Switzerland) containing the sponge-like collection devices. Times of container openings were electronically detected and stored by MEMS containers. Thus, participants' adherence to the sampling instructions was objectively verifiable. The use of MEMS devices has been shown to increase adherence to the assessment protocol (Kudielka, Broderick, & Kirschbaum, 2003).

2.4. Prospective memory

Before starting the testing session the child played some unrelated warm-up games with the experimenter. To maintain children's motivation, the hand-puppet "Smiley" accompanied the testing session, cheered up the children, and constantly encouraged them to play the game.

A ball sorting game was applied as a PM task in which the intention had to be executed when a specific cue occurred (see Kvavilashvili et al., 2008 for methodological guidelines). As the ongoing task, the experimenter rolled 24 colored balls to the children. Three to four years old children were asked to sort balls according to their color (blue, red, green, yellow) into respective colored baskets and children aged 5 years and older were asked to sort balls according to their color and size (blue, red, green,