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Stress during transition from home to public childcare

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ABSTRACT

Four saliva probes were collected per day from 104 children (10 to 35 months old) transitioning from home (T0) to childcare across a four-month period (until T3), resulting in over one thousand cortisol values. Latent Profile Analysis classified three profiles within a regular spectrum of children's cortisol rhythms and described a fourth hypocortisol stress profile. Further Latent Transition Analysis revealed that profiles frequently changed across the transition but stabilized at T3. Most importantly, regular profiles across transition most likely occurred with high AQS scores of mother-child and care provider–child attachment. A machine learning procedure (XGBoost) featured predictors for stress profiles at T3 (when the child ought to be adjusted and stress profiles should be rare) referring to characteristics of the children (e.g., gender, number of siblings, peer contact before entry), the mothers (their worries), the care providers (their work experience, engagement, attachment) and the groups in the childcare centers (e.g., size, age differences, illness frequency). As a result, experience with siblings and peers before entry facilitated the transition. However, most conditions not linearly affecting children's cortisol revealed even opposite effects when analyzed at different times. For example, smaller group size and large age-differences at T1 helped the child to stabilize a *Regular* profile, perhaps due to better control over the situation and greater support from the older children in the group. At T3, however, *Regular* profiles were associated with larger group size and smaller age-differences which might be helpful for establishing close peer relationships to buffer stress.

Several decades of comprehensive research on children being cared for at home and in public childcare, whether the facilities were run by government, church, companies or private organizations, has demonstrated how children benefit from the enriching experiences based on the Early Childhood Education and Care (ECEC) arrangements (see metanalysis by van Huizen & Plantenga, 2018). However, researchers have also questioned whether these facilities, which are predominantly organized in childcare centers (Lamb & Ahnert, 2006), are appropriate for children under three. They have been particularly concerned that the transition to center-based childcare and experiences of group life create stress that might adversely affect child well-being (Ahnert et al., 2004; Datler et al., 2012; Fein et al., 1993; Klein et al., 2010; Nystad et al., 2021; Rauh et al., 2000).

Transition to childcare

Childcare researchers forced investigations on young children's health status and psychobiological functioning during the rapidly expanding center-based childcare systems in Eastern Europe in the 1970s. A mega study on more than 6.000 children from Russian, Bulgarian, Czechoslovakian, and East German childcare centers revealed severe sleep disruptions, digestive problems and infectious diseases associated with childcare entry. Consequently, parental leave policy was expanded and changes in the entry practice were introduced, which allowed a parent to accompany the child at entry (see Schmidt-Kolmer et al., 1979). Later studies in Austria (Datler et al., 2012; Ereky-Stevens et al., 2018), Germany (Ahnert et al., 2004; Rauh et al., 2000), Italy (Fein et al., 1993), Israel (Klein et al., 2010) and Norway (Nystad et al., 2021) explored children's behavioral adjustment during the transition in more detail. For example, Rauh and her colleagues (Rauh et al., 2000) explored children's levels of irritability and negative mood post entry in the context of an abrupt vs. prolonged enrollment with mothers' accompaniment. The study clearly demonstrated that a prolonged enrollment made the

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transition easier than an abrupt entry, which amplified children's negative emotions. Ahnert et al. (2004) used three cortisol measures in the morning to track stress responses when toddlers were dropped off at childcare centers. They reported that the effect of mothers' accompaniment was dependent on the quality of mother-child attachment, provided securely attached toddlers had markedly lower cortisol levels than their insecure counterparts. This clearly suggested that trusting relationships buffer the stress of childcare entry. When the daily mother-child separations began, however, cortisol levels were elevated in all toddlers. Fein and her colleagues (Fein et al., 1993) reported that levels of negative affect and immobilization persisted six months post entry, even though the care providers attended to the unhappy children the most. Klein et al. (2010) observed that toddlers who cried more following separation received more attention and care providers' distracting responses, whereas those who cried less received more empathic responses. Overall, this suggests that care providers have limited capacities to reduce children's stress, in particular when children's behaviors considerably change over time (Datler et al., 2012). The present study therefore asked how challenging the entire transition from home to childcare for the stress response system in young children is in general, and whether care providers are able to effectively support children to cope with the stress.

Stress in young children

Advances in noninvasive measurement techniques, such as the development of salivary assays, have facilitated analyses of cortisol in child stress research (e.g., Gunnar et al., 2009). Cortisol is the primary hormonal product of the Hypothalamic-Pituitary-Adrenocortical (HPA) axis, which is central to children's stress response system. The HPA axis releases cortisol according to a circadian rhythm, i.e., cortisol reaches the highest level after waking and declines across the day with the lowest levels at night. Circadian regulation of the HPA axis in young children, however, matures into the third year as expected by progressive myelinization of the prefrontal cortex and maturation of brain functioning, and corresponds with other areas of development such as sleep-wake cycles (Gunnar & Quevedo, 2007). Specifically, cortisol levels may fluctuate with the natural midday naps of young children and rebound after the child wakes up in order to lower cortisol levels again. As follows, cortisol in young children might sometimes increase (or remain elevated) following naps (see Gribbin et al., 2012; Tervahartiala et al., 2020; Tribble et al., 2015; Ward et al., 2008; Watamura et al., 2004). In contrast to the steady decline of cortisol release over a day in adults, this diurnal cortisol rhythm in young children is disrupted in form of a *bump* or a *plateau* as demonstrated by cortisol collections ranging from morning to evening (Groeneveld et al., 2010; Sumner et al., 2010). Interestingly, disruptions in declining diurnal cortisol foremost appeared if naptimes were ordered (Thorpe et al., 2018). Ordered naptime (in contrast to demand-driven naps by children themselves), however, is a common practice in center-based childcare centers of mediocre to low quality. Not surprisingly, past research linked rising cortisol levels after the naps in centers' afternoons to low childcare quality (Geoffroy et al., 2006; Vermeer & van IJzendoorn, 2006).

Stress in young children is not easy to capture, as the stress response system comprises a complex repertoire of central neural and peripheral neuroendocrine responses designed to prepare the organism for challenge or threat. Neurobiologically mediated sensitivity to context as well as adaptive calibration through developmental experience might be responsible for the striking amount of individual variations with narrow and wide reaction norms of HPA axis activations, as outlined in *Biological Sensitivity to Context* [BSC] theory by Boyce and Ellis (2005) and *Adaptive Calibration Model* [ACM] by Del Giudice et al. (2011). Naturalistic cortisol research describes reaction norms by the overall shape of the cortisol patterns across the day. The shape is indexed by the diurnal slope with large slopes, shown as a steep drop in cortisol from morning to evening, rated as *healthy* (Miller et al., 2007; Saxbe, 2008).

Both theories argue that, in general, infrequent HPA axis activations in the first years of life might up-regulate the stress response system, and lead to increasing responsivity toward stress. Thereby children develop sufficiently wide reaction norms to respond to regular environmental stressors. If the reaction norm stays narrow, however, these children would show adequate elevated response levels toward stress in a protected environment, where they are supported in keeping stress in check. In an uncontrollable environment (where support is not predictable), a child with a narrow reaction norm might have difficulty developing responsivity toward stress, and eventually down-regulate the HPA axis, producing lower levels of cortisol.

Table 1. Mid-morning and mid-afternoon cortisol in studies on children's stress in public childcare.

Authors	Sample	Cortisol [µg/dl] mid-morning	Cortisol [µg/dl] mid-afternoon	Context	Children's Age/Gender
Drugli et al. (2018)	Norwegian	.25	.22	home	
		.25	.29	center-based*	
Sumner et al. (2010)°	USA	.14	.12	home	
		.14	.20	center-based*	
Groneveld et al. (2010)	Dutch	.14	.11	home	
		.12	.11	center-based	
		.13	.14	home-based*	
Quellet-Morin et al. (2010)	Canadian	.14 /.15	.10 /.14	home	two-year olds
		.14 /.14	.14 /.18	center-based*	two-year old boys*
		.25 /.32	.20 /.21	home	three-year olds
		.14 /.12	.14 /.12	center-based	three-year olds
Watamura et al. (2003)	USA	.22 /.16	.18 /.17	home	infants/toddlers
		.31 /.21	.26 /.39	center-based*	infants/toddlers*
Vermeer et al. (2010)	Dutch	.11	.10	home	
		.13	.12	center-based	
	Basque	.20	.10	home	
		.14	.11	center-based (half day attendance)	
		.13	.14	home	
		.11	.10	center-based (full day attendance)	

Note. °Measures are confirmed by M. Dozier (personal communication); *Studies demonstrating rising midmorning to midafternoon cortisol.

Interestingly, whereas the conventional view on elevated cortisol in response to stress is widely used in child stress research, blunted diurnal cortisol rhythm is foremost in the focus of adult stress and overlooked in developmental studies (see Gunnar & Vazquez, 2001). The present study aimed to substantiate full variations in children's HPA axis activities during transition from home to childcare. Specifically, we described how children's diurnal cortisol rhythms change in order to adapt to repeated exposures to the childcare setting. We thereby focused on wide and narrow reaction norms as indicated by regular and blunted cortisol profiles.

Stress in public childcare

The HPA axis engages when children face unpredictable and/or uncontrollable challenges requiring anticipation, which still is developing in early childhood. Moreover, HPA axis in young children is exceptionally responsive if the challenges involve threat to the relationship with parents, and separation from them (Ahnert et al., 2004), as well as due to stressful peer interactions (Vermeer & van IJzendoorn, 2006). Two metaanalyses have shown that the effect of childcare on cortisol was less prevalent during children's first compared to their second year of life (Geoffroy et al., 2006; Vermeer & van IJzendoorn, 2006). In fact, little stress research has been conducted in children aged between 12 and 36 months; and only very rarely is research on children's diurnal cortisol based on repeated measures spread out from morning over afternoon to evening and bedtime, comparing the cortisol measures at home and in childcare (c.f., Groeneveld et al., 2010; Sumner et al., 2010).

Most studies used only two cortisol measures to examine changes in cortisol from midmorning to midafternoon. Although these studies carefully compared cortisol levels from the same child in childcare and at home, findings are mixed (see Table 1 for an overview). Some of these studies reported increases in midmorning to midafternoon cortisol (when cortisol is expected to decline) in center-based care, but not at home (Drugli et al., 2018; Sumner et al., 2010). This confirms Vermeer and van IJzendoorn (2006)'s speculation that children in center-based care (particularly children under three) show elevated cortisol levels due to their stressful interactions in a group setting. They conclude the greater the groups and noise levels and the lower caregiver sensitivity (summarized as low childcare quality), the more children's cortisol levels might increase.

In Groeneveld et al. (2010)'s study, however, there were no afternoon increases in center-based care. Oddly enough, the study instead revealed cortisol increases in home-based childcare, where children experienced higher caregiver sensitivity, lower noise levels, and also demonstrated higher wellbeing compared to children in childcare centers. Ouellet-Morin and her colleagues (Ouellet-Morin et al., 2010) found increasing cortisol from midmorning to midafternoon in center-based childcare only in two-year old boys (not girls). One year later, this effect had totally disappeared. Watamura and her colleagues (Watamura et al., 2003) revealed increasing cortisol in the afternoons of childcare centers, mostly in toddlers (71%) and occasionally in children younger than 16 months

(35%). Vermeer and her colleagues (Vermeer et al., 2010) completely failed to find any differences in the analysis of midmorning to midafternoon changes in cortisol at home and in childcare centers. Overall, researchers often sampled children's saliva after the afternoon nap (and before they received a small snack, typically provided following the nap) in the centers. This suggests a systematic influence of the nap on midafternoon cortisol, especially when considering that ordered naps in mediocre to low quality childcare might have triggered midafternoon cortisol more in childcare than at home. Not surprisingly, only almost half of the examined samples of past research showed raising midmorning to midafternoon cortisol, and these were, interestingly, at similar levels across the studies despite the different technologies used to analyze saliva cortisol.

Past research also aimed to identify stress-buffering effects as well as stressors in childcare predicting children's HPA axis activation. For example, social relationships tend to dampen children's stress responses (Ahnert et al., 2004; Hostinar et al., 2014). However, associations of care providers' sensitivity with children's cortisol in childcare provided controversial results (Groeneveld et al., 2010). Still, researchers believe in trustful care providers who help children to hold the stress response in check post enrollment to childcare, even though empirical evidence on whether this support works in the context of group care is still outstanding. Furthermore, Legendre (2003), who repeatedly measured cortisol in childcare across morning hours, found several stressors for increased cortisol release: large group sizes ($n > 15$), large age differences among children within the group (>6 months), less available area per child in the playrooms ($<5\,m^2$), and large numbers of adults in the room (>4 adults). Ouellet-Morin and her colleagues (Ouellet-Morin et al., 2010) revealed that children with less peer contact before enrollment had higher cortisol in childcare than enrolled children with previous peer contact. There are also some associations of cortisol in childcare with frequencies of peer play (Watamura et al., 2003), hours in childcare centers (Drugli et al., 2018), and illness frequency (Watamura et al., 2010).

Overall, the debate on stressors in childcare points to the fact that home and childcare environments are quite contrasting experiences for young children (Ahnert & Lamb, 2003). The present study therefore investigated relevant features, which enhance or dampen young children's HPA axis activities, specifically when the children enter childcare for the first time.

Study aims

In this article, we examined children's cortisol responses throughout the transition from home to childcare, and uncovered how and under what conditions the diurnal cortisol rhythms changed or remained stable. Based on four measures per day, we inspected children's cortisol on three sections of the transition along a four-month timeline. The study ought (1) to describe children's diurnal cortisol generally in a way that differentiates between *Regular* and *Stress* cortisol profiles. Taking into account theoretical considerations on the striking amount of individual variations in cortisol rhythms with narrow and wide reaction norms, we expected several types of *Regular* profiles in many daily situations as well as a *Stress* profile appearing in situations with obvious stressors. (2) Pacing *Regular* and *Stress* profiles throughout the transition, we explored how children's HPA axis activities changed in order to adapt to the repeated exposures to childcare. We hypothesized that children's *Regular* profiles would be more likely at home and at the end of the transition whereas *Stress* profiles should be most frequent at childcare entry. Moreover, children's attachment experiences with parents and care providers should affect changes in children's cortisol throughout the transition. We thus expected that high quality relationships of the children to their parents and care providers would buffer children's stress responses in childcare and thereby assure *Regular* profiles. (3) We finally aimed to reveal features of child, caregiver and environmental characteristics, which still predict stress at the end of the transition. Based on past childcare research, we assumed that environmental characteristics like large group size and children's age differences within the group would make *Stress* profiles more likely. In contrast, children's experience with siblings and peers as well as care providers, who display professional and empathetic behaviors, should prevent the children from experiencing stress and thus make *Stress* profiles less likely.

Methods

Sample

The present research is part of a larger study on the transition from home to childcare (see Datler et al., 2012; Ereky-Stevens et al., 2018), during which we focused on children's cortisol responses and accepted responsibility for this part of the study. The Ethics Committee of the Medical University of Vienna (Austria) approved the present study. We received written informed consent of all families involved in the study who agreed to support the saliva collection for cortisol analyses.

Homes

The 104 families involved in the study were representative of middle-to-upper class and of Caucasian ethnicity, with 42.2% of the mothers and 46.5% of the fathers having graduated either from high school or university. Mothers were $M = 35;2$ ($SD = 4;8$) years, and fathers $M = 37;4$ ($SD = 6;1$) years old. Ninety-three percent of the mothers were married or lived together with the fathers of the target child, and 7% were single mothers. The 104 children (57 female; 47 firstborns) were between 10 and 35 months ($M = 23;0$, $SD = 4;8$) old, healthy and born at term. The families were recruited from childcare centers in Vienna (Austria), where the parents had applied for their children's attendance. All children were cared for at home prior to childcare entry. At entry, children were accompanied by their mothers for approximately one to two weeks ($M = 7$ workdays, $SD = 5.9$).

Parental leave policy

Parental leave policy in Austria assures high flexibility for parents to care for their children at home, with or without the help of public childcare, during infancy and toddlerhood. While the jobs are protected after delivery, parents can take leave and are strongly encouraged to take it in a shared way. Parental shared leave can be taken according to four different time frames of 14, 18, 24 or 36 months (more details in Valarino et al., 2018). In the present study, 87.5% of the mothers took parental leave for an average of 21.1 months ($SD = 7.6$) and 11.8% of the fathers for an average of 10.8 months ($SD = 8.6$). Furthermore, the Austrian government financially supports the families based on two models, i.e., a one-year income-based model and a flat rate-based model with flexible eligibility of the timeframes up to 36 months. Both models aim to financially support families of various SES and thus enable them to share the time with their children, primarily according to their wishes (and hardly due to their financial needs). Although the flat rate-based model tends to be more attractive for student and low-income families, whereas the income-based model (with the couple receiving 80% of the salary of the parent who takes leave) might be more attractive for socially privileged families, the length of parental leave did not correlate with SES in the present study (for mothers: $r = -.050$, *n.s.*; for fathers: $r = -.073$, *n.s.*). According to answers in multiple-choice questionnaires, parents most frequently reported that they ended parental leave because of (1) better developmental challenges for the child due to educational programs in public childcare (78.2%), (2) more peer contact in the child's social life and better play opportunities (77.2%), and more personal freedom for self-development and marital relationship (41.6%).

Childcare

Children entered 84 classrooms of 71 childcare centers located in diverse districts of Vienna (Austria). Of the centers, 49.1% were run by the state, 16.3% by the church, and 34.6% by parent initiatives. The childcare centers ranged from mediocre to high quality (see Datler et al., 2012; Ereky-Stevens et al., 2018). Group sizes varied between 10 and 23 children ($M = 16.06$; $SD = 3.08$), with age differences among the children in a group between 6 and 60 months ($M = 28;6$, $SD = 15;1$). Child–care provider ratio ranged between 1:3 and 1:20, excluding one additional assistant who was often available for the group. The target children's primary care providers were professional females, who had passed a three- to five-year vocational training. They were between 19 and 59 years old ($M = 34;5$, $SD = 10;9$) with work experience between 1 and 38 years ($M = 12;2$, $SD = 10;2$). The present study finally yielded a nested data structure because 22 of the involved childcare centers recruited more than one target child, and 11 primary care providers were included multiple times in the study, as they were observed with more than one child (up to four) throughout the 28-month recruitment period.

Overall procedure

We visited the families and children at home almost two weeks before entry (T0), interviewed the parents about family structure (including number of children, gender and birthdates), SES and family life, including the target child's contact to other children in the neighborhood, at play groups and playgrounds (rated on a 5-point Likert scale from "rare" to "most frequent"). During the home visit, we also collected saliva for the first time and instructed the parents on how to collect the saliva later on. We eventually observed the attachment relationship between mother and child, and left a questionnaire on *Maternal Separation Anxiety*, which the mother was to return at childcare entry (and was to answer again around two months later).

Almost one-month post entry, we visited the target children in the childcare center for the first time (T1), once they had experienced the new environment two weeks with and two weeks without a parent present. We continued with two subsequent visits in the centers and scheduled them two months (T2) and four months (T3) post entry. We collected saliva from the children each time (T1, T2 and T3). We also registered the current group size and the age difference among the children of the group to which the target child was assigned as well as child's hours at the center and illness frequencies. In addition, we observed care providers' engagement, and assessed the care provider–child attachment relationship at T2 and T3. We finally requested details on care provider's age, family background, and career (i.e., type of training and years of work experience).

Measures

Cortisol

We measured cortisol based on saliva, which was collected at home by parents and in the centers by care providers or research assistants, respectively, and instructed all not to collect saliva during food or drink consumption.

Cortisol collection. At home before childcare entry (T0) and across the transition (at T1, T2, and T3), saliva collections took place four times a day: (1) in the morning between 7:30 and 8:30 AM, (2) midmorning between 10:30 and 11:30 AM, (3) midafternoon between 2:00 and 3:00 PM, and (4) evening between 6:00 and 7:00 PM. According to the suggestion of the lab, which later analyzed the probes, we used no oral stimulants for the saliva selection but simple sterile Eye Spears on which the children sucked. Once the Eye Spears were saturated, they were placed in an airproof micro tube and stored at 0 °F/−18 °C until they were assayed in the lab.

Cortisol quantification. The lab of the Biopsychological Department at Technical University in Dresden, Germany (headed by Clemens Kirschbaum) analyzed all saliva probes. It applied Enzyme Immuno Assay (EIA) "Synelisa Sensitive" and reported a sensitivity of .2 μg/dl cortisol in concentrations of 0 to 10 μg/dl. Using 10 μl saliva samples, both intra- and interassay variability were less than 10% in concentrations of .4 to .7 μg/dl cortisol. All probes were assayed in duplicate to ensure reliability. Ideally, these analyses would have produced four cortisol profiles (based on four measures each) for each target child before (T0) and along the transition (T1, T2 and T3) yielding 404 patterns. However, 17% of the measures were missing due to insufficient sampling. Overall, 1081 probes could be analyzed, resulting in 335 diurnal cortisol patterns for 101 children; for three children, missing cortisol values were so dreadful that we had to fully exclude them from statistical analyses (see later).

Children's attachment relationships

External observers rated children's attachment relationships to their mothers as well as their primary care providers with the German version of the Attachment Q-Sort during two-hour observations (AQS: Waters, 1995; Ahnert et al., 2012). The AQS captures children's attachment during everyday situations, which thus allowed for an ecological description of attachment in families and childcare centers. In preparation for the attachment observations, six research assistants were intensively trained for the AQS procedure using video training and live observations. Later, ten video records that had been rated by experts determined whether the observers had reached an interrater reliability of at least $ICC = .75$ before they served as external observers in the present study. In addition, two observers carried out about 10% of the observations simultaneously before they observed alone. Observers of the present study achieved an excellent reliability with $ICC = .90$.

According to the test construction of the AQS, the observer must sort 90 items into 9 piles (with 10 cards each) from "most descriptive" to "least descriptive" of the dyad. Items describe situations when the child searches for proximity to the mother/care provider (e.g., *Child keeps track of mother/care provider's location when he plays around the house*; item 21), enjoys proximity (e.g., *Child often hugs or cuddles against mother/care provider, without her asking or inviting her to do so*; item 11), likes to share and obey (e.g., *Child follows mother/care provider's suggestions readily, even when they are clearly suggestions rather than orders*; item 18) etc. The sorting of all items was then correlated with an expert's sorting that describes a perfect secure adult-child attachment. The correlation resulted in AQS scores ranging from −1.0 to +1.0, with scores representing the extent of attachment security.

We received AQS scores for mothers (AQS-M) at T0 ranging from −.27 to .74 ($M = .38$, $SD = .18$).

Attachment scores for care providers (AQS-CP) were obtained at T1, T2, and T3 and ranged between −.28 and .67 (M = .26, SD = .17). To ensure normal distribution for later statistics, we objected all AQS scores to Fisher's r-to-z transformation.

Maternal worries

To capture maternal worries, we utilized the *Maternal Separation Anxiety Scale* (MSAS; Hock et al., 1989). Mothers filled out the 35 Likert self-report scales, which taped three independent subscales. The present article used only the subscale *Perception of Separation Effects on the Child*. The subscale score refers to seven items, ranging from 7 to 35, and obtains high scores if a mother believes her child will not benefit from public childcare. Cronbach's alpha proved sufficient reliability with .75.

Care provider engagement

External observers assessed care provider engagement based on the *Global Scale of Caregiver Behavior* (CIS: Arnett, 1989). The present article focused on the subscale *Disengagement*, which contains six items. These 4-point Likert scales (ranging from "often" to "never") describe the amount of care provider interest and involvement in children's day-to-day activities in the center (reversed). Nine research assistants trained the *Global Scale of Caregiver Behavior* via video records before they used the scale for observations. The research assistants verified reliability based on the first 44 observations which two raters had simultaneously observed, but separately rated, and achieved reliability of ICC = .74.

Analytic plan

We conducted three separate but related sets of analyses. *First*, a latent profile analysis (LPA) grouped homogenous patterns of the four cortisol measures per day and child to cortisol profiles, and assigned a probability of group membership for each pattern, so that the cortisol patterns were examined within the group they most probabilistically belonged to (Flaherty & Kiff, 2012). We applied a two-level LPA to treat cortisol measures per day and child in relation to the longitudinal measures collected from home throughout the transition. This modeling approach thus allowed identifying cortisol profiles, which represent children's HPA axis activities as variations of the diurnal cortisol rhythms over time.

Because the diurnal trajectories of the cortisol were central for profile identification, we considered the exact sampling time of each cortisol level. In addition, experiences in working with children taught us that where the cortisol had been collected might be influential on cortisol levels. Beside exact sampling time, LPA thus controlled for the location of the measures, i.e., at home or in childcare. Missing cortisol values were a challenge too. All values of a diurnal cortisol pattern that had missing morning values or sole morning values were not included in LPA, because the trajectories of the diurnal cortisol rhythms could not be reliably determined. For all remaining missing values, however, we used full information maximum likelihood (FIML) allowing efficient model estimation based on all available data (Enders, 2010).

As a key result of LPA, Bootstrap likelihood ratio tests (BLRT) eventually determined the optimal number of profiles, and assessed whether a k-profile would fit the data better than a $k-1$ profile solution (see Nylund et al., 2007). For the appraisal of the final model, relative Entropy E, ranging from 0 to 1, indicated how separable the classes were, with the closer E to 1 the better. When LPA modeling identified different cortisol profiles across the transition, it provided us with the opportunity to recognize three of them as children's wide and narrow reaction norms of the HPA axis dynamics. We condensed the three profiles to one *Regula*r category, which we later contrasted with the remaining *Stress* category.

Second, to examine how the *Regular* and *Stress* profiles had changed or were maintained over time, we used a Latent transition analysis (LTA), where transition probabilities indicate the likelihood of a child being assigned to the *Regula*r profile at time point t, given that this child was already assigned to this profile at time point $t-1$ or had been shifted from the *Stress* profile (see Collins & Lanza, 2010; Nylund, 2007). We focused on three different sections along the transition: (1) TRANS 1 covered the time between T0 and T1 when target children started childcare, and their mothers accompanied them for a while. Because mothers went back to work in the middle of TRANS 1, however, children must learn to adjust to the daily separations. (2) TRANS 2 related to the time from T1 to T2 when the children familiarize with the childcare setting and rules, and (3) TRANS 3 concerned the time between T2 and T3 when group dynamics and peer interactions became important.

LTA tested changes and stability of children's *Regular* vs. *Stress* profiles throughout the three transition sections, and whether and how children's attachment to their mothers (AQS-M score) and their primary care providers (AQS-CP score) influenced

Table 2. Model fit indicators for two- to five-class solutions.

Classes	BLRT *p* (k – 1 vs k)	Entropy	AIC	BIC
2	<.001	.77	5259.7	5344.8
3	<.001	.67	5206.0	5329.9
4	<.001	.70	5129.0	5291.6
5	>.999	.67	5123.3	5328.5

this process, also controlling for child age. A general index of model fit for LTA was again provided by Relative Entropy *E* with the better fit being *E* closer to 1. Estimated transition coefficients, *b*, indicated stability or change of children's cortisol profiles through the three sections of the transition, and regression coefficients *b* indicated attachment influences on the likelihood of *Regular* vs. *Stress* profiles at each transitional section.

Third, we were interested in features affecting the final Stress profile at the end of the transition (T3). Having recorded 30 features per child for each of the 104 children, traditional statistics would not be able to determine which of the features would be predictive or not. As suggested by Chen and Guestrin (2016), we used XGBoost, a machine learning technique that uses decision tree modeling for predictions and other decision-making challenges over sets of features. In the respective tree structures, leaves represent class labels, and branches represent conjunctions of features that lead to those class labels. In the present analysis, XGBoost does recursive partitioning in order to split the features along cortisol profiles into parts of similar relations. Based on a multiple classification tree procedure, XGBoost iteratively adds trees while steadily reweighting the features and their relations (among them and with the cortisol profiles), thereby handling any nonlinear relations. In addition, a value for feature importance indicated the relative contribution of a feature to the model calculated by each feature's contribution for each tree. If a feature showed a higher value of this metric when compared to another feature, it implied that the feature with a higher value was more important to generating a prediction than the other. With XGBoost, we were eventually able to identify relevant features from the current data collection in order to predict the likelihood of a *Regular* vs. *Stress* profile, and indicate the importance of the prediction. In addition, XGBoost made the results graphically interpretable with Shapley additive explanations (SHAP: Lundberg & Lee, 2017).

We conducted LPA and LTA with MPlus 8.2 (Muthén & Muthén, 2017), and used the MLR estimator. WE conducted XGBoost and SHAP with R package XGBoost 0.82.1 (Chen et al., 2019). SMOTE, an oversampling procedure, was necessary later on (see below) and we used R package DMwR 0.4.1 for this (Torgo, 2010).

Table 3. Matrix of the distribution of cortisol profiles (%) across types and times throughout the transition.

	Time Points Across the Transition				
Profile Types	T0	T1	T2	T3	∑%
I	5.3	5.1	5.2	6.2	21.8
II	6.7	6.6	6.9	6.1	26.3
III	**10.9**	7.7	8.1	8.1	34.8
IV	2.2	**8.1**	3.6	3.2	17.1
∑ %	25.1	27.5	23.8	23.6	100

Note. T1 = Time 1; T2 = Time 2; T3 = Time 3; TRANS = defined sections of the transition: TRANS 1 from T0 to T1; TRANS 2 from T1 to T2; TRANS 3 from T2 to T3.

Results

Regular vs. Stress profiles

Based on the latent profile analyses, we found support for four different homogenous classes of cortisol profiles. BLRT (<.001) preferred the four-class solution with $E = .70$ as an optimal LPA model. (For all fit indices see Table 2; for class sizes and distribution see Table 3). Comparison of the three, four and five-class solutions implied that the addition of a fifth class did not significantly improve model fit, that is, 3 vs. 2, $p < .001$, and 4 vs. 3, $p < .001$ but 5 vs. 4, $p > .999$).

As a result, we assigned 21.8% of the diurnal cortisol patterns to Profile I, 26.3% to Profile II, 34.8% to Profile III and the rest of 17.1% to Profile IV (see Figure 1). The first three Profiles I, II and III demonstrated variations of morning cortisol levels which averaged at .40 µg/dl at equivalent times of day in children who had either no experience with childcare or were already adjusted (Ahnert et al., 2004; Sumner et al., 2010). The profiles' cortisol levels at midmorning and midafternoon were also comparable with past research, ranging between .10 to .35 µg/dl before and after noon (see Table 1). They all showed characteristic cortisol declines over a day, with Profile I having a *bump* while Profile III, however, displayed a *plateau* between midmorning and midafternoon cortisol as a distinct feature.

In contrast, Profile IV yields a completely blunted shape of low cortisol release, which scholars of stress recognize as hypocortisol pattern, and evaluate as a deviant HPA axis response in a stressful environment (e.g., Fries et al., 2005; see Figure 1).

In order to explore whether Profile IV appeared more frequently at times of stressful encounters, and whether Profiles I, II and III were almost equally frequent across time and location, we arranged a matrix in which all profiles were spread over the study design

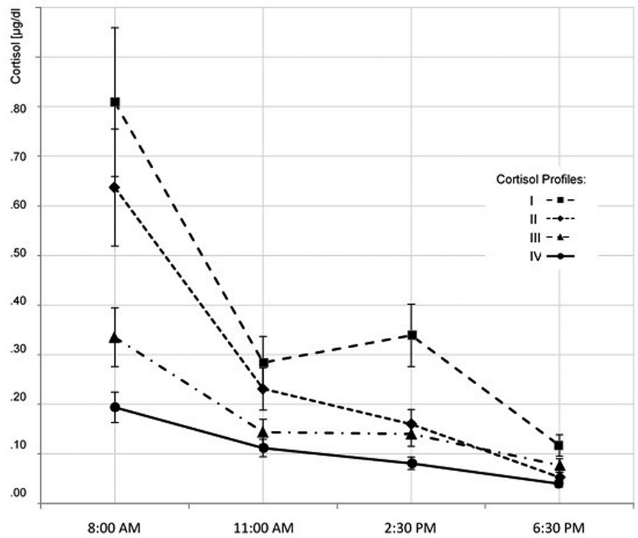

Figure 1. Children's cortisol profiles characterized by mean and SEM of the assigned cortisol measures.

Table 4. Child-oriented description on stability and change of regular vs. stress profiles.

	TRANSITIONS			Sample	
	⟶ TRANS 1	⟶ TRANS 2	⟶ TRANS 3	*n*	%
Regular (T0)	Regular (T1)	Regular (T2)	Regular (T3)	58	57.4
Regular (T0)	Regular (T1)	Stress (T2)	Stress (T3)	4	4.0
Regular (T0)	Regular (T1)	Regular (T2)	Stress (T3)	3	3.0
Regular (T0)	Regular (T1)	Stress (T2)	Regular (T3)	1	1.0
Regular (T0)	Stress (T1)	Regular (T2)	Regular (T3)	11	10.9
Regular (T0)	Stress (T1)	Stress (T2)	Stress (T3)	7	6.9
Regular (T0)	Stress (T1)	Regular (T2)	Stress (T3)	1	1.0
Regular (T0)	Stress (T1)	Stress (T2)	Regular (T3)	7	6.9
Stress (T0)	Regular (T1)	Regular (T2)	Regular (T3)	7	6.9
Stress (T0)	Regular (T1)	Stress (T2)	Stress (T3)		
Stress (T0)	Regular (T1)	Regular (T2)	Stress (T3)		
Stress (T0)	Regular (T1)	Stress (T2)	Regular (T3)		
Stress (T0)	Stress (T1)	Regular (T2)	Regular (T3)	1	1.0
Stress (T0)	Stress (T1)	Stress (T2)	Stress (T3)	1	1.0
Stress (T0)	Stress (T1)	Regular (T2)	Stress (T3)		
Stress (T0)	Stress (T1)	Stress (T2)	Regular (T3)		

Note. T1 = Time 1; T2 = Time 2; T3 = Time 3; TRANS = defined sections of the transition: TRANS 1 from T0 to T1; TRANS 2 from T1 to T2; TRANS 3 from T2 to T3.

(see Table 3). Whereas Profile IV with 2.2% of the sample was rare at T0, its likelihood indeed peaked immediately at T1 when the child was just enrolled in public childcare, $\chi^2(1) = 4.82$, $p = .028$. Interestingly, an additional χ^2-test (for T1 cortisol only, including child age and the duration of maternal accompaniment) revealed that Profile IV was more likely when the maternal accompaniment was long (>4 days) and the children young (under 24 months), $\chi^2(2) = 4.44$, $p = .035$. In other words, the profile was linked to children's entry, and in particular, to younger children whose mothers took more time to accompany them. For that reason, we determined Profile IV as *Stress* profile.

In contrast, all other profiles (Profiles I, II and III) spread almost equally across the transition (see Table 3), regardless of whether they showed *bumps* or *plateaus* as we would not expect if these profiles were associated with stress. Profile III (showing the lowest cortisol levels among Profiles I, II and III) was significantly more frequent than all other profiles at T0 with young children (less than 24 months), $\chi^2(3) = 9.2$, $p = .027$). Profile III might thus represent a narrow reaction norm of the stress response system. To ease further analytic work, we combined all regular profiles (Profile I, II and III) to one *Regular* profile and contrasted it against the *Stress* profile.

Stability and change in cortisol profiles across transition and the impact of attachment

Focusing on *Regular* vs. *Stress* profiles, we first inspected stability and change across the transition. As demonstrated in Table 4, *Regular* profiles exhibited the highest stability throughout the entire transition from home to childcare, with 57.4% of the children displaying this profile. 15.9% of the children showed a *Stress* profile only once, followed by 11.9% who responded with a *Stress* profile at two sections during the transition. Across the three sections of the transition, 7.9% of the children maintained a *Stress* profile, and only one child continued from home throughout the entire transition with a blunted cortisol pattern. As described in Table 5, however, frequencies of *Regular* (vs. *Stress*) profiles changed enormously from 92 (vs. 9) down to 73 (vs. 28) during TRANS 1, when the children coped with the new situation, and the separation from the mother. During TRANS 2, when care providers familiarized the children with the childcare rules, *Regular* profiles improved from 73 (vs. 28) to 81 (vs. 20) and remained stable across TRANS 3, that is, minimal *Regular* profile improvement from 81 (vs. 20) to 85 (vs. 16).

Assuming that attachment experiences of the children (as indexed by AQS-M and AQS-CP) influenced children's cortisol rhythms during the transition, we included AQS-M and AQS-CP scores in the LTA model at the same time as we tested stability and change of the cortisol profiles. Figure 2 describes the model construction: We included AQS-M, which we had measured only once at home, even though we assumed that children's attachment to the mother affects children's cortisol profiles across the entire transition. We included AQS-CP measured at T1 and T2 and expected children's attachment to the primary care providers to be associated with children's cortisol profiles during TRANS 2 and 3, when the care providers familiarized and helped to integrate the

Table 5. Transition-oriented description on stability and change of regular vs. stress profiles by numbers of children.

	TRANS 1 (Adjusting)			TRANS 2 (Familiarizing)			TRANS 3 (Integrating)		
Profiles	ALL	Regular	Stress	ALL	Regular	Stress	ALL	Regular	Stress
Regular	92	66	26	73	68	5	81	77	4
Stress	9	7	2	28	13	15	20	8	12
ALL	101	73	28	101	81	20	101	85	16

Note. Numbers refer to children who changed or retained a *Regular* vs. *Stress* profile during three sections of the transition, i.e., TRANS 1, 2, and 3.

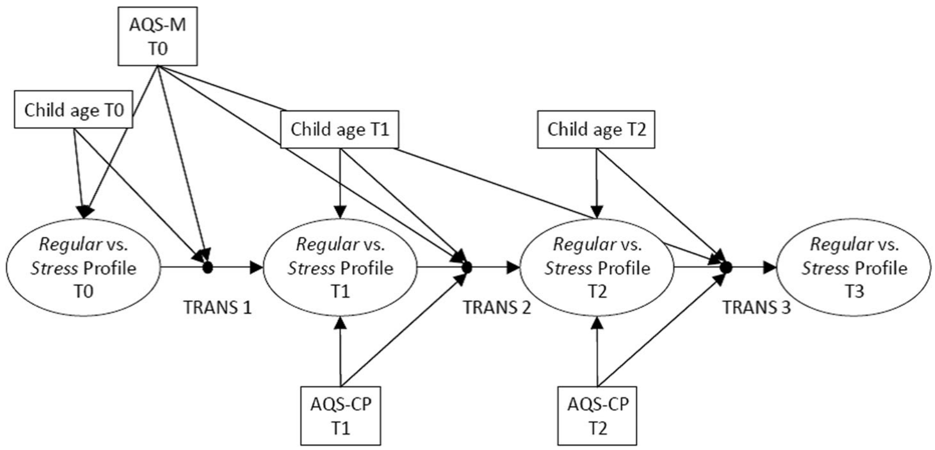

Figure 2. Latent transition model of regular vs. stress cortisol profiles throughout the transition.

Table 6. Attachment experiences predicting stability and change in cortisol profiles during the transition.

	Regular at T-1			Stress at T-1		
Attachment	*b*	*SE*	*p*	*b*	*SE*	*p*
		TRANS 1				
Mother (T0)	−0.02	0.95	.99	1.33	4.23	.75
		TRANS 2				
Mother (T0)	6.53	2.79	.019*	1.05	2.74	.70
Care Providers (T1)	6.95	5.80	.23	−1.67	2.85	.37
		TRANS 3				
Mother (T0)	−0.65	1.62	.69	13.80	5.99	.021*
Care Providers (T2)	−2.01	2.50	.40	30.74	13.64	.024*

Note. T = Time of attachment observations (AQS): T0 = before, T1/T2 = one and two months post entry; TRANS = defined sections of the transition: TRANS 1 from T0 to T1; TRANS 2= from T1 to T2; TRANS 3 from T2 to T3; all transitions were controlled by child age (*T*s ranging from -1.89 to 2.56, n.s.); *p>.05.

children into childcare. LTA model furthermore controlled all AQS predictors for their effects on contemporaneous cortisol profiles. Because of the age bias in children's cortisol release, we finally included child age. LTA reached an excellent model fit with $E = .95$ (see Figure 2).

Overall, children's cortisol profiles appeared highly instable during TRANS 1 ($b = -0.78$, $p = .66$) as well as TRANS 2 ($b = 7.45$, $p = .12$), whereas during TRANS 3, children's cortisol profiles persisted ($b = -8.61$, $p = .031$), suggesting that a *Regular* or *Stress* profile in children at T2 most likely continued to T3. Moreover, LTA clearly revealed that the attachment experiences of the children were associated with their cortisol profiles. Three outcomes stood out (see Table 6): (1) the higher the AQS-M score, the more likely children's cortisol responses gained on *Regular* profiles during TRANS 2 ($b = 6.53$, $p = .019$) and (2) the more likely *Regular* profiles retained during TRANS 3 ($b = 13.80$, $p = .021$). (3) The higher the AQS-CP score, the more likely children's cortisol stabilized a *Regular* profile against the *Stress* profile during TRANS 3 ($b = 30.74$, $p = .024$). Child age had no systematic impact on the changes in children's cortisol.

Stress at the end of the transition

Only 15.8% of the children displayed a *Stress* profile at the end of the transition (T3), whereas 84.2% demonstrated *Regular* profiles. To explore the circumstances associated with the likelihood of these results, we applied XGBoost and tested 30 (categorical and continuous) features retrieved from the recruitment records. Features such as child and family characteristics, mother and care provider characteristics and a long list of characteristics describing the quality of the center, were of interest. However, the low percentage of *Stress* profiles in contrast to the high percentage of *Regular* profiles in the current sample posed a major analytical challenge, which we overcame with synthetic minority oversampling (SMOTE: Chawla et al., 2002). Here, the key idea is

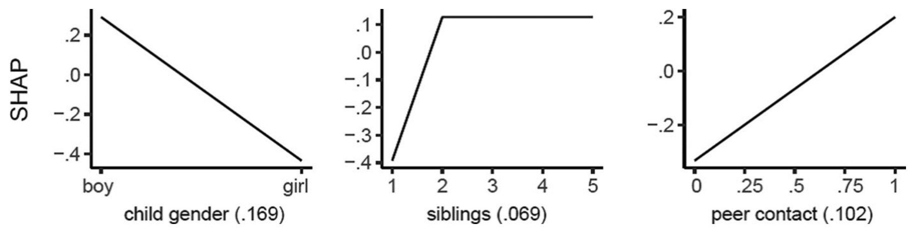

Figure 3a. Child characteristics as related to regular profiles at the end of transition.

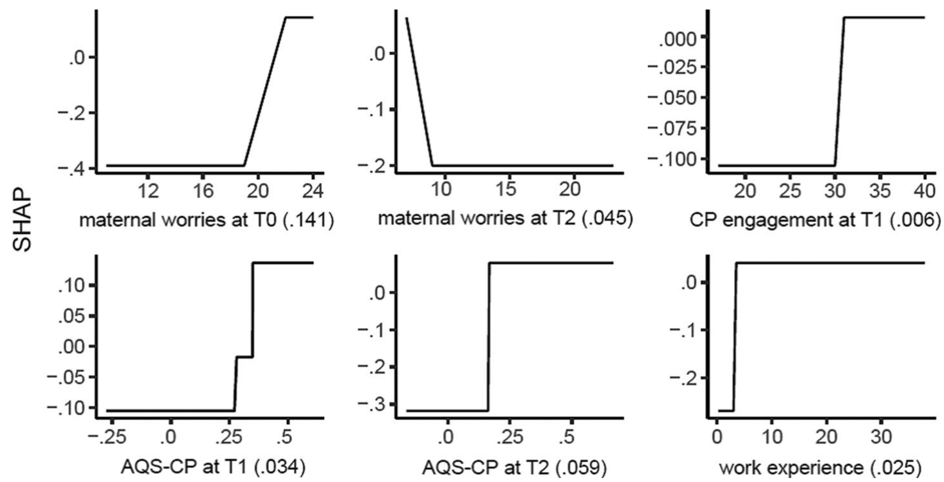

Figure 3b. Characteristics of mothers and care providers as related to regular profiles at the end of transition.

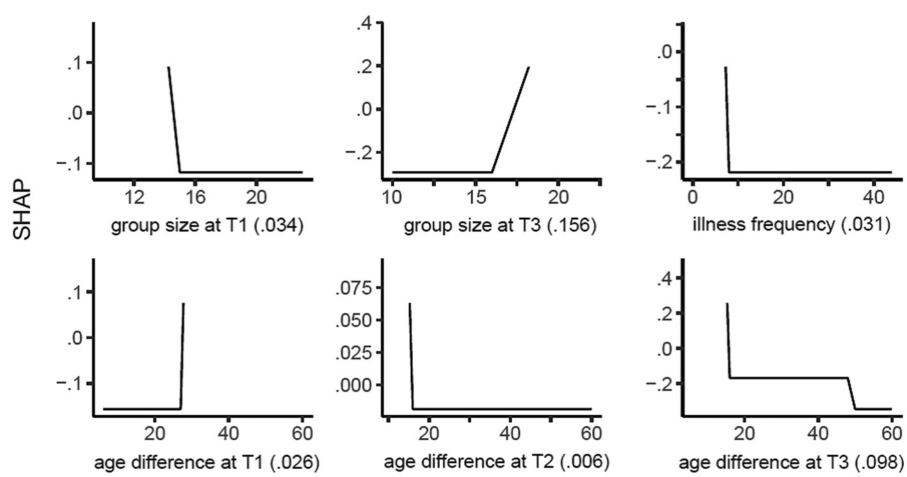

Figure 3c. Group characteristics as related to regular cortisol profiles at the end of transition.

to use synthetically generated data based on the original data. In other words: SMOTE uses the feature space of either group to create new data within the local feature boundaries. In preparing SMOTE, 10% of the data (randomly selected) were removed and used as a hold-out sample to later check whether the model built on SMOTE's synthetic data would be similar to the model built on the empirical data. Synthetic cases are not identical to the original ones, but they are random variations of what the algorithm expects from new cases to be close to the empirical data. SMOTE synthesized the data within the feature space of the five nearest neighbors per case. The sampling rate was set to modes of 500% over- and 120% under-sampling, which produced a synthetic sample of 72 *Stress* and 72 *Regular* profiles. On this data set, XGBoost (Chen & Guestrin, 2016) trained a model that eventually comprised 87 decision trees. Evaluation on the synthetic data yielded $AUC_{SMOTE} = .97$, on the original data $AUC_{train} = .87$, and on the hold-out data $AUC_{hold\text{-}out} = 1.0$, which indicate excellent fit and generalizability of the results.

Fifteen features out of 30 predicted whether children's cortisol profile was either a *Regular* or a *Stress* profile at T3. Moreover, XGBoost indicated how crucial certain features for the prediction were, using feature importance values which ranged from .169 (child male gender) to .006 (age difference of the children within a group). In addition, SHapley Additive exPlanations (Lundberg & Lee, 2017) made detailed interpretations for each feature possible. Accordingly, a feature more likely predicted (along its value range) a *Stress* profile, the more negative its SHAP values were, and in turn, indicated a *Regular* profile the more positive its SHAP values were (see Figure 3a–c). The 15 features described child, caregiver and group characteristics of the centers. Child gender (male) and frequent experience with siblings or peers before childcare entry stood out, compared to many other child characteristics, in making a *Regular* cortisol profile more likely the more prevalent these characteristics were (see Figure 3a).

Furthermore, among many of the caregiver characteristics, mothers' worries verified a *Stress* profile the more the worries sustained into late transition (T2) but not if they existed before enrollment (T0) when the worries might have been productive in preparation of the child's entry. Furthermore, care providers' engagement at child's entry (T1) most likely contributed to a *Regular* profile. As expected, care providers' attachment to the child (AQS-CP at T1 and T2) predicted *Regular* profiles. In addition, short work experience already contributed to a *Regular* profile, even though this feature was not as important (feature importance of .025) as care provider–child attachment was with .034 and .059 (see Figure 3b).

Interesting insights also appeared with regard to the group characteristics in the centers. These features predicted children's cortisol profiles as related to their timing. For example, large group sizes predicted *Stress* profiles at T1 when children also coped with the separation from the mother. At T3, when the target children began to familiarize with the group, large groups were more likely associated with *Regular* profiles, helping the child to regulate better physiologically. Similar predictions referred to age differences of the children in the group the target child had entered. Whereas large age differences predicted *Regular* profiles the larger they were at the beginning of the transition (T1), by the T2 and T3, however, large age differences were more likely to predict *Stress* profiles, suggesting that the group dynamic over time had changed. Noteworthy also, illness frequency in the middle of the transition predicted *Stress* profile at the end; see Figure 3c.

Discussion

Past research reported severe effects on behavioral and biopsychological functioning when young children enter a childcare center for the first time and stay for long hours (e.g., Ahnert et al., 2004; Fein et al., 1993; Rauh et al., 2000). The present study therefore examined HPA axis activities across a four-month transition period from home to childcare and focused on children's diurnal cortisol rhythms. Based on a collection of over one thousand saliva samples, we utilized four cortisol measures per day and child, and described diurnal cortisol profiles for 101 children over the transition.

A Latent Profile Analysis classified four types of cortisol profiles, of which one stood out with very low morning levels and flat trajectories (Profile IV). Profile IV peaked at the very beginning of the transition (T1), obviously responding to children's stressors. The profile appeared even more frequent when children were young (under 24 months), and mothers' accompaniment was long. We therefore determined Profile IV as the *Stress* profile. In contrast, Profile I, II, and III showed the typical decline of cortisol levels over a day. Although these profiles varied tremendously in terms of their cortisol levels, they were in line with data from other studies on cortisol in the morning between .40 and .80 µg/dl, at midmorning between .11 and .25 µg/dl and at midafternoon between .10 and .39 µg/dl (see overview in Table 1). Moreover, no matter whether the profiles showed *bumps* or *plateaus* in their trajectories, they spread equally over the transition, as one would never expect if they were associated with stress. We therefore condensed them into one *Regular* profile, and found support in the theoretical framework of wide and narrow reaction norms of normal HPA axis responses (see Boyce & Ellis, 2005; Del Giudice et al., 2011). Suggesting narrow reaction norms, children with Profile III showed the lowest cortisol levels as opposed to Profile I and II. Moreover, Profile III already appeared at home (T0), and in particular in young children. In contrast, children with Profile I or II showed higher cortisol levels and declines, and appeared independent of child age and time of the transition. This suggests wider reaction norms and easier adjustment to any of the new situations of the transition.

The present study also described the distribution of *Regular* vs. *Stress* profiles throughout the transition, with 57.4% of all children showing only *Regular* profiles but no *Stress* profile. About 15.9% of the children showed a *Stress* profile just once during the transition, followed by 11.9% who showed a *Stress* profile twice. 7.9% of the children developed and maintained a *Stress* profile from childcare entry onwards, and one child continued with a *Stress* profile already from home throughout the entire transition. A latent transition model confirmed that children's cortisol profiles were quite instable as of two months post entry (T2). Afterwards, cortisol profiles stabilized and made reliable predictions from T2 to T3, i.e., children with Stress profiles at T2 most likely also showed a Stress profile at T3, even though there was no effect of child age on this process. The prediction suggests that parents and care providers definitely need to intervene (and not wait longer) if a child does not feel well after two months of enrollment (T2) to ensure the child does not have to face prolonged stress.

Furthermore, the transition model showed how experiences of attachment security with the mothers and the primary care providers in the centers helped the children to stabilize changes in cortisol rhythms. The more securely attached a child was to the mother, the more likely children's cortisol gained on *Regular* profiles throughout the transition. Most importantly, the more securely attached a child was to the care provider, the more likely cortisol stabilized a *Regular* against a *Stress* profile. Thus, children's attachment experiences clearly buffer children's stress responses during the transition. Even when children had already overcome the daily separations from their mothers, and were familiar with life in the childcare center, they were less likely to develop a *Stress* profile if they had experienced attachment security with their mothers. Similarly, during the time when children got more involved with the group and peers: the more pronounced children's security was to their mothers, the less likely children displayed a *Stress* profile. The present study thus goes much further than Ahnert et al. (2004)'s study which argued that mothers might not be able to help children's adjustment when they are no longer accompanying them. The children need their homes beside good care in public centers. Full-day observations of toddlers whose parents shared the care with public childcare centers revealed that toddlers demand a considerable amount of attention when mothers picked them up, yet not during the hours in childcare, perhaps to emotionally re-equilibrate (see Ahnert et al., 2000; Ahnert & Lamb, 2003). Surely, when children get to know the challenges in the group, they absolutely need supportive care providers. Not surprisingly, the higher children's level of attachment security was to their care providers, the less likely children displayed a *Stress* profile at the end of the transition.

Furthermore, the present study detected and confirmed stressors, which might be in part avoidable when children make the transition to childcare centers. Most of the predictors not linearly affecting children's cortisol are part of a complex nonlinear dynamic system where small changes might lead to huge effects and vice versa. We thus browsed through a huge data file of possible predictors and used a machine learning procedure (XGBoost) not only to select important predictors but also to reveal their importance at different times during the transition. For example, mothers' worries regarding their children's enrollment before the entry predicted *Regular* profiles at the end of the transition. Perhaps the worries might have been beneficial in easing the transition process. In contrast, maternal worries in the midst of the transition (measured two months post entry) indicated a higher likelihood of *Stress* profiles at the end.

Another example for a time-connected impact on children's cortisol were group characteristics. Smaller group size at the beginning but a larger group size at the end of the transition helped the child to stabilize a *Regular* profile, with the same effect being shown for large age-differences among the peers at the beginning and smaller age-differences at the end. Clearly, when a child is new to the group, small group sizes might be helpful to have better control over the situation, and large age-differences among the peers might mean that particularly the older children may find the newcomer interesting and show support. When the child, however, has adjusted, opposite conditions can turn into advantages: larger group size and smaller age-differences might be helpful for selecting peers with whom friendships can buffer stress. These findings are in line with Legendre (2003), who captured group effects on children's cortisol in public childcare. Other predictors of children's stress confirmed known associations too. For example, illness frequency is an alarming indicator for enduring stress responses (see Watamura et al., 2010), and only-children or children with less peer contact before enrollment and girls tend to show *Stress* profiles in childcare (Ouellet-Morin et al., 2010).

In sum, the present study provides evidence that children's stress during the transition from home to childcare can be socially buffered by high quality adult-child relationships and supporting conditions in the centers. However, the study must also discuss its limitations. *First,* the sample was too small to include more existing data in the present models. For example, we were not able to examine the spectrum of *Regular* cortisol profiles in more detail, or to investigate the impact of wide and narrow reaction norms of children's stress response system along the transition. More complex modeling, however, would improve our understanding of the transition process and would make the current results stronger. *Second,* the small sample size drove us to model the transition with the standard LTA instead of RI-LTA to separate within- and between-person processes. Clearly, the standard LTA tends to underestimate change probabilities, meaning the actual effects are robust but might be greater than reported. *Third,* the first section of the transition (TRANS 1) combines to two contradicting events, that is, maternal accompaniment and maternal separation. This might be the reason why we failed to find elevated cortisol in responses (hypercorticolism) to the childcare entry and only children's instable profiles during this time. *Fourth,* we used a machine learning approach to learn how variations of the public care environment are associated with children's stress response system. It allowed us to distill those environmental factors from a large data set that effectively associate with HPA axis activities of the children. However, results are only explorational and cannot replace statistical testing on a larger sample. *Fifth*, the study focused on the childcare environment and widely left influences of the family environment out (except mother-child attachment). However, it more precisely controlled for effects of the home environments when evaluating effects of the public childcare environments on children's stress response system during the entire transition. *Sixth*, we did not include behavioral measures of children's stress during the transition because this issue would have overloaded the present article. Behavioral expressions, however, are eventually important when wanting to derive illustrative recommendations for childcare practice.

The present article represents a time-consuming and costly study, which is rare in childcare research. We analyzed over one thousand cortisol values (four measures per day and child), as we were convinced we must map the diurnal course of the cortisol release as children's transitions from home to childcare might be too complex to be explored only by two measures (midmorning-midafternoon). We also collected many additional factors that are known to influence the childcare attendance (including attachment, various child-related and environmental factors). In the end, the extensive data collection alone did not help to model children's transition perfectly. The relatively small sample size (104 children) caused limitations (see above). Given that high costs were already in place, future research on the stress response system calls for national and international collaborations. Taking this into consideration, researchers must find ways to overcome one of the main hindrances, i.e., that cortisol data cannot be merged across research labs because of different assay technology.

Author note

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Disclosure statement

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References

Ahnert, L., Eckstein-Madry, T., Supper, B., Bohlen, U., Suess, E. S., & Suess, G. J. (2012). *Waters' attachment Q-sort according to German translation and application* (Unpublished manuscript). University of Vienna.

Ahnert, L., Gunnar, M. R., Lamb, M. E., & Barthel, M. (2004). Transition to child care: Associations with infant-mother attachment, infant negative emotion, and cortisol elevations. *Child Development*, *75*(3), 639–650. https://doi.org/10.1111/j.1467-8624.2004.00698.x

Ahnert, L., & Lamb, M. E. (2003). Shared care: Establishing a balance between home and child care settings. *Child Development*, *74*(4), 1044–1049. https://doi.org/10.1111/1467-8624.00587

Ahnert, L., Rickert, H., & Lamb, M. E. (2000). Shared caregiving: Comparison between home and child care. *Developmental Psychology*, *36*(3), 339–351. https://doi.org/10.1037/0012-1649.36.3.339

Arnett, J. (1989). Caregivers in day-care centers: Does training matter? *Journal of Applied Developmental Psychology*, *10*(4), 541–552. https://doi.org/10.1016/0193-3973(89)90026-9

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. An evolutionary–developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology*, *17*(2), 271–301. doi: 10.10170S0954579405050145

Chawla, N. V., Bowyer, K. W., Hall, L. O., & Kegelmeyer, W. P. (2002). SMOTE: Synthetic minority over-sampling technique. *Journal of Artificial Intelligence Research*, *16*, 321–357. https://doi.org/10.1613/jair.953

Chen, T., He, T., Benesty, M., Khotilovich, V., Tang, Y., Cho, H., & Li, Y. (2019). XGBoost: Extreme gradient boosting. R package version 0.82.1. https://CRAN.R-project.org/package=xgboost

Chen, T., & Guestrin, C. (2016). XGBoost: A scalable tree boosting system. In *Proceedings of the 22nd acm sigkdd international conference on knowledge discovery and data mining* (pp. 785–794). ACM.

Collins, L. M., & Lanza, S. T. (2010). *Latent class and latent transition analysis: With applications in the social, behavioral, and health sciences*. Wiley.

Datler, W., Ereky-Stevens, K., Hover-Reisner, N., & Malmberg, L. E. (2012). Toddlers' transition to out-of-home day care: Settling into a new care environment. *Infant Behavior & Development*, *35*(3), 439–451. https://doi.org/10.1016/j.infbeh.2012.02.007

Del Giudice, M., Ellis, B. J., & Shirtcliff, E. A. (2011). The adaptive calibration model of stress responsivity. *Neuroscience and Biobehavioral Reviews*, *35*(7), 1562–1592. https://doi.org/10.1016/j.neubiorev.2010.11.007

Drugli, M. B., Solheim, E., Lydersen, S., Moe, V., Smith, L., & Berg-Nielsen, T. S. (2018). Elevated cortisol levels in Norwegian toddlers in childcare. *Early Child Development and Care*, *188*(12), 1684–1695. https://doi.org/10.1080/03004430.2016.1278368

Enders, C. K. (2010). *Applied missing data analysis*. Guilford.

Ereky-Stevens, K., Funder, A., Katschnig, T., Malmberg, L. E., & Datler, W. (2018). Relationship building between toddlers and new caregivers in out-of-home childcare: Attachment security and caregiver sensitivity. *Early Childhood Research Quarterly*, *42*, 270–279. https://doi.org/10.1016/j.ecresq.2017.10.007

Fein, G. G., Gariboldi, A., & Boni, R. (1993). The adjustment of infants and toddlers to group care: The first 6 months. *Early Childhood Research Quarterly*, *8*(1), 1–14. https://doi.org/10.1016/S0885-2006(05)80095-X

Flaherty, B. P., & Kiff, C. J. (2012). Latent class and latent profile models. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), *APA Handbook of research methods in psychology*, Vol. 3. Data analysis and research publication (pp. 391–404). APA. https://doi.org/10.1037/13621-019

Fries, E., Hesse, J., Hellhammer, J., & Hellhammer, D. H. (2005). A new view on hypocortisolism. *Psychoneuroendocrinology*, *30*(10), 1010–1016. https://doi.org/10.1016/j.psyneuen.2005.04.006

Geoffroy, M.-C., Côté, S. M., Parent, S., & Séguin, J. R. (2006). Daycare attendance, stress, and mental health. *Canadian Journal of Psychiatry. Revue Canadienne de Psychiatrie*, *51*(9), 607–615. https://doi.org/10.1177/070674370605100909

Gribbin, C. E., Watamura, S. E., Cairns, A., Harsh, J. R., & LeBourgeois, M. K. (2012). The cortisol awakening response (CAR) in 2- to 4-year-old children: Effects of acute nighttime sleep restriction, wake time, and daytime napping. *Developmental Psychobiology*, *54*(4), 412–422. https://doi.org/10.1002/dev.20599

Groeneveld, M. G., Vermeer, H. J., van IJzendoorn, M. H., & Linting, M. (2010). Children's well-being and cortisol levels in home-based and center-based childcare. *Early Childhood Research Quarterly*, *25*(4), 502–514. https://doi.org/10.1016/j.ecresq.2009.12.004

Gunnar, M. R., & Vazquez, D. M. (2001). Low cortisol and a flattening of expected daytime rhythm: Potential indices of risk in human development. *Development and Psychopathology*, *13*(3), 515–538. https://doi.org/10.1017/S0954579401003066

Gunnar, M. R., Talge, N. M., & Herrera, A. (2009). Stressor paradigms in developmental studies: What does and does not work to produce mean increases in salivary cortisol. *Psychoneuroendocrinology*, *34*(7), 953–967. https://doi.org/10.1016/j.psyneuen.2009.02.010

Gunnar, M., & Quevedo, K. (2007). The neurobiology of stress and development. *Annual Review of Psychology*, *58*, 145–173. https://doi.org/10.1146/annurev.psych.58.110405.085605

Hock, E., McBride, S., & Gnezda, M. T. (1989). Maternal separation anxiety: Mother-infant separation from the maternal perspective. *Child Development*, *60*(4), 793–802. https://doi.org/10.2307/1131019

Hostinar, C. E., Sullivan, R. M., & Gunnar, M. R. (2014). Psychobiological mechanisms underlying the social buffering of the hypothalamic-pituitary-adrenocortical axis: A review of animal models and human studies across development. *Psychological Bulletin*, *140*(1), 256–282. https://doi.org/10.1037/a0032671

Klein, P. S., Kraft, R. R., & Shohet, C. (2010). Behaviour patterns in daily mother–child separations: Possible opportunities for stress reduction. *Early Child Development and Care*, *180*(3), 387–396. https://doi.org/10.1080/03004430801943290

Lamb, M. E., & Ahnert, L. (2006). Nonparental child care. In W. Damon, R. M. Lerner, K. A. Renninger & I. E. Sigel (Eds.), *Handbook of child psychology: Volume 4: Child psychology in practice* (5th ed., pp. 950–1016). Wiley.

Legendre, A. (2003). Environmental features influencing toddlers' bioemotional reactions in day care centers. *Environment and Behavior*, *35*(4), 523–549. https://doi.org/10.1177/0013916503035004005

Lundberg, S. M., Lee, S.-I. (2017). A unified approach to interpreting model predictions. In *Proceedings of the 31st International Conference on Neural Information Processing Systems* (pp. 4768-–4777). Curran Associates Inc.

Miller, G. E., Chen, E., & Zhou, E. S. (2007). If it goes up, must it come down? Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. *Psychological Bulletin*, *133*(1), 25–45. https://doi.org/10.1037/0033-2909.133.1.25

Muthén, L. K., & Muthén, B. O. (2017). *Mplus user's guide*. Muthén & Muthén.

Nylund, K. L. (2007). [*Latent transition analysis: Modeling extensions and an application to peer victimization*]. [Doctoral thesis]. Retrieved from http://www.statmodel.com/download/Nylund%20dissertation%20Updated1.pdf.

Nylund, K. L., Asparouhov, T., & Muthén, B. O. (2007). Deciding on the number of classes in latent class analysis and growth mixture modeling: A monte carlo simulation study. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(4), 535–569. https://doi.org/10.1080/10705510701575396

Nystad, K., Drugli, M. B., Lydersen, S., Lekhal, R., & Buøen, E. S. (2021). Toddlers' stress during transition to childcare. *European Early Childhood Education Research Journal*, *29*(2), 157–182. https://doi.org/10.1080/1350293X.2021.1895269

Ouellet-Morin, I., Tremblay, R. E., Boivin, M., Meaney, M., Kramer, M., & Cote, S. M. (2010). Diurnal cortisol secretion at home and in child care: A prospective study of 2-year-old toddlers. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *51*(3), 295–303. doi:10.1111/j.1469-7610.2009.02167.x

Rauh, H., Ziegenhain, U., Müller, B., & Wijnroks, L. (2000). Stability and change in infant-mother attachment in the second year of life: Relations to parenting quality and varying degrees of day-care experience. In M. P. Crittenden & H. A. Claussen (Eds.), *The organization of attachment relationships: Maturation, culture, and context* (pp. 251–276). Cambridge.

Saxbe, D. E. (2008). A field (researcher's) guide to cortisol: tracking HPA axis functioning in everyday life. *Health Psychology Review*, *2*(2), 163–190. https://doi.org/10.1080/17437190802530812

Schmidt-Kolmer, E., Tonkowa-Jampolskaja, R., & Atanassowa, A. (1979). *Die soziale Adaptation der Kinder bei der Aufnahme in Einrichtungen der Vorschulerziehung [Childrens' social adaptation post enrollment into public childcare]*. Verlag Volk und Gesundheit.

Sumner, M. M., Bernard, K., & Dozier, M. (2010). Young children's full-day patterns of cortisol production on child care days . *Archives of Pediatrics & Adolescent Medicine*, *164*(6), 567–571. https://doi.org/10.1001/archpediatrics.2010.85

Tervahartiala, K., Karlsson, L., Pelto, J., Kortesluoma, S., Hyttinen, S., Ahtola, A., Junttila, N., & Karlsson, H. (2020). Toddlers' diurnal cortisol levels affected by out-of-home, center-based childcare and at-home, guardian-supervised childcare: comparison between different caregiving contexts. *European Child & Adolescent Psychiatry*, *29*(9), 1217–1229. https://doi.org/10.1007/s00787-019-01432-3

Thorpe, K. J., Pattinson, C. L., Smith, S. S., & Staton, S. L. (2018). Mandatory naptimes in childcare do not reduce children's cortisol levels. *Scientific Reports*, *8*(1), 4545–4552. https://doi.org/10.1038/s41598-018-22555-8

Torgo, L. (2010). *Data mining with R: Learning with case studies*. Chapman and Hall.

Tribble, R. C., Dmitrieva, J., Watamura, S. E., & LeBourgeois, M. K. (2015). The cortisol awakening response (CAR) in toddlers: Nap-dependent effects on the diurnal secretory pattern. *Psychoneuroendocrinology*, *60*, 46–56. https://doi.org/10.1016/j.psyneuen.2015.05.009

Valarino, I., Duvander, A.-Z., Haas, L., & Neyer, G. (2018). Exploring leave policy preferences: A comparission of Austria, Sweden, Switzerland, and United States social politics. *Social Politics: International Studies in Gender, State & Society*, *25*(1), 118–147. https://doi.org/10.1093/sp/jxx020

van Huizen, T., & Plantenga, J. (2018). Do children benefit from universal early childhood education and care? A meta-analysis of evidence from natural experiments. *Economics of Education Review*, *66*, 206–222. https://doi.org/10.1016/j.econedurev.2018.08.001

Vermeer, H. J., & van IJzendoorn, M. H. (2006). Children's elevated cortisol levels at daycare: A review and meta-analysis. *Early Childhood Research Quarterly*, *21*(3), 390–401. https://doi.org/10.1016/j.ecresq.2006.07.004

Vermeer, H. J., Groeneveld, M. G., Larrea, I., van IJzendoorn, M. H., Barandiaran, A., & Linting, M. (2010). Child care quality and children's cortisol in Basque Country and The Netherlands. *Journal of Applied Developmental Psychology*, *31*(4), 339–347. https://doi.org/10.1016/j.appdev.2010.05.001

Ward, T. M., Gay, C., Alkon, A., Anders, T. F., & Lee, K. A. (2008). Nocturnal sleep and daytime nap behaviors in relation to salivary cortisol levels and temperament in preschool-age children attending child care. *Biological Research for Nursing*, *9*(3), 244–253. https://doi.org/10.1177/1099800407310158

Watamura, S. E., Coe, C. L., Laudenslager, M. L., & Robertson, S. S. (2010). Child care setting affects salivary cortisol and antibody secretion in young children. *Psychoneuroendocrinology*, *35*(8), 1156–1166. https://doi.org/10.1016/j.psyneuen.2010.02.001

Watamura, S. E., Donzella, B., Alwin, J., & Gunnar, M. R. (2003). Morning-to-afternoon increases in cortisol concentrations for infants and toddlers at child care: Age differences and behavioral correlates. *Child Development*, *74*(4), 1006–1020. https://doi.org/10.1111/1467-8624.00583

Watamura, S. E., Donzella, B., Kertes, D. A., & Gunnar, M. R. (2004). Developmental changes in baseline cortisol activity in early childhood: Relations with napping and effortful control. *Developmental Psychobiology*, *45*(3), 125–133. https://doi.org/10.1002/dev.20026

Waters, E. (1995). Appendix A: The attachment Q-set (Version). *Monographs of the Society for Research in Child Development*, *60*(2/3), 234–246. https://doi.org/10.2307/1166181