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Delay of gratification and time comprehension is impaired in very preterm children at the age of 4 years

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ABSTRACT

Background: Very preterm infants more likely exhibit deficient executive functions than term born controls. Delay of gratification, as part of the executive functions, allows for rejecting an immediate in favor of a greater future reward. Time comprehension might help to delay gratification.

Aims: We hypothesized that delay of gratification and time comprehension is less developed in preterm children and that time comprehension is associated with the ability to wait for a greater reward.

Study design: Very preterm children (< 32 weeks' gestation) and term born controls were tested for receptive language skills, time comprehension and delay of gratification at the (corrected) age of 4 years.

Subjects: 25 preterm subjects (12 female; median: gestational age (GA) 28.3 weeks, corrected age 4 years, 22 days) and 26 controls (16 female, median GA: 40.0 weeks, age 4 years, 25 days) participated.

Outcome measures: Correct answers in the time comprehension and receptive language task, waiting time in the delay-of-gratification task were measured.

Results: Preterm subjects had less time comprehension than controls (43% vs. 53%, $p = 0.017$, one-tailed) but receptive language skills were similar. Waiting time in the delay-of-gratification task was 3:42 min in preterm subjects, versus 10:09 min in controls ($p = 0.043$, one-tailed). Even after controlling for language skills, waiting time correlated positively with time comprehension in both groups ($r = 0.399$, $p = 0.004$, two-tailed).

Conclusions: Preterm children's time comprehension and delay of gratification ability is impaired. Future research is warranted to investigate whether training in time comprehension increases the ability to delay gratification.

1. Introduction

Premature birth incorporates an increased risk for neurocognitive deficits, behavioral problems; attention deficit (hyperactivity) syndrome and autism spectrum disorders in future life [1–3]. Cognitive impairments comprise lower intelligence quotient (IQ) in former preterm infants as well as poorer performance in executive function tasks compared to controls [4–6]. Deficits persist into adulthood [6,7] and are considered responsible for lower educational qualifications and net income [8,9]. Executive functions have been described as key factors for lower academic achievement and behavioral problems [10,11], and are influenced by gestational age (GA), birth weight and morbidities deriving from the perinatal period [12,13].

According to Diamond there are three core executive functions: inhibitory control, working memory and cognitive flexibility, that develop at different paces from infancy to adulthood. For example, inhibitory control is far more difficult for young children than for adults [7,14].

Inhibitory control describes the ability to resist temptations or control impulsive reactions and to modulate emotional expressions. Inhibitory control in early childhood predicts life perspectives (physical and mental health, personal finances, addiction to substances, delinquency and crime) [15]. Thus, developing inhibitory control abilities is vital for children in order to navigate through their social environment.

In preterm infants, Jaekel et al. described a correlation of low GA at birth with lower inhibitory control in childhood. Low inhibitory control was predictive for lower attention regulation and academic

Abbreviations: GA, gestational age; IQ, intelligence quotient; MRI, magnetic resonance imaging; yrs, years

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achievement at the age of 8 years [16]. Therefore it is important to identify children with poor inhibitory control as much as it is crucial to reveal possible starting points for training programs to promote those children at highest risk.

A reliable method of measuring inhibitory control is the delay-of-gratification task [17,18]. It has been shown that children's ability to wait for a greater reward in the delay-of-gratification task develops between the age of 3–4 years and correlates with children's understanding of temporal terms (e.g. “tomorrow” or “before”) [19,20]. Few studies, however, relate the ability to delay gratification to time perception [21] during childhood [22,23] and adolescence [24], suggesting that children's concept of time develops in synchrony with their ability to refrain from acting on impulse. A general misconception of time intervals might lead individuals with low inhibitory control to overestimate the waiting period in relation to the value of the additional reward. To our knowledge the development of time comprehension in very preterm infants and its relation to inhibitory control abilities has not been investigated to date.

In the present study, the first hypothesis was that very preterm children fall behind term children in their ability to delay gratification and in their time comprehension. The second hypothesis was that delay of gratification correlates with time comprehension independent of the GA at birth. It was furthermore conceivable that understanding of temporal terms might also be based on linguistic capacities. Thus, the third hypothesis was that the correlation of both functions remains valid after controlling for receptive language skills.

2. Material and methods

2.1. Participants

Preterm participants were recruited from 89 surviving very preterm born infants admitted between April 2010 and March 2012 to the Neonatology department of the University Hospital Essen, University of Duisburg-Essen, Germany. Inclusion criteria were: preterm birth < 32 weeks' gestation and corrected age of 48–50 month. Exclusion criteria were severe disabilities and insufficient German language skills. For comparison 30 healthy term born children (> 37 weeks' gestation) were enrolled. They were either peers of preterm participants or recruited in daycare centers or by advertisement on the hospital website and newsletter. One preterm and three term participants had to be excluded due to experimenter error, (n = 3) and insufficient language skills (n = 1). Table 1 presents characteristics of the 25 very preterm and 26 term born participants.

The study was approved by the local ethical committee of the University of Duisburg-Essen, Germany (13-5461_BO). The experiments were performed in accordance with the Declaration of Helsinki. One of the legal representatives gave informed written consent prior to participation.

2.2. Experimental setting

The study was performed in a specifically designed room (2.0 × 2.5 m), empty of distractions, with a one-way mirror and furnished only with a child-sized table, two child-sized chairs, and an extra chair for one parent. A camera for video recording was placed near the ceiling in a corner of the room enabling panoramic observation of the setting (see Fig. 1).

2.3. Design & procedure

All participants completed three different tasks in a randomized order: a receptive-language-test (SETK 3-5, German language development test for 3 to 5 year olds, [25]), a time-comprehension-task (hourglass-test [26]), and a delay-of-gratification task [18]. The investigator was blinded to the medical history of preterm children. Tasks started after a short interval of warming-up where children were offered to draw a picture with the investigator. Parents were allowed to stay in the room during warm up, language- and time-comprehension-tasks. Furthermore, parents were asked to complete a questionnaire on socio-economic status and parental education. Perinatal data were taken from Germany's official documentation of healthcare visits, birth charts or hospital records.

Table 1
Clinical characteristics of participating children.

	Prenatal children (n = 25)	Control children (n = 26)
Demographic characteristics		
Age in yrs. and d – mean (range)	4, 27 (4, 1–4, 57)	4, 28 (4, 8–4, 58)
Sex – male/female – n	12/13	16/10
Parental education (maternal; paternal)[a]		
Level 0 – n (%)	1(4%); 0 (0%)	0 (0%); 0 (0%)
Level I – n (%)	2 (8%); 3 (12%)	0 (0%); 2 (7.7%)
Level II – n (%)	4 (16%); 9 (36.0%)	1 (3.8%); 1 (3.8%)
Level III – n (%)	18 (72%); 12 (48%)	25 (96.2%); 23 (88.5%)
Perinatal characteristics		
Gestational age at birth in weeks – median (range)	28.29 (24.0–31.43)	40.0 (37.14–42.14)
Birth weight in grams – median (range)	1060 (590–1850)	3337 (2430–4280)
Small for gestational age (< 10th centile) – n (%)	3 (12%)	0 (0%)
5-min APGAR score – median (range)	8 (4–10)	10 (9–10)
10-min APGAR score – median (range)	9 (7–10)	10 (9–10)
Umbilical artery pH – median (range)	7.35 (7.13–7.43)	7.31 (7.15–7.43)
AIS – no/yes/unknown – n	18/5/2	0/0/0
Antenatal steroids – no/yes/unknown – n	2/21/2	26/0/0
Bronchopulmonal dysplasia – n (%)	2 (8)	n.a.
Retinopathia praematuorum > grade 2 – n (%)	6 (24)	n.a.
Persistent ductus arteriosus – n (%)	17 (68)	n.a.
Postnatal characteristics	**n = 23**	**n = 26**
Proven sepsis – no/yes/unknown – n	17/6/2	0/0/0
Postnatal steroids – no/yes/unknown – n	20/3/2	0/0/0
Cerebral ultrasonography (postnatal period)	**n = 24**	
Intraventricular hemorrhage[b] – n (%)	4 (16.7%)	n.a.
Grade I – n	3 (12.5%)	n.a.
Grade II – n	1 (4.2%)	n.a.
Periventricular leukomalacia at TEA – n	0 (0%)	n.a.
Cerebral MRI at term equivalent age	**n = 24**	
Intraventricular hemorrhage[b] – n/(%)	7 (29%)	n.a.
Grade I – n (%)	5 (21%)	n.a.
Grade II – n (%)	2 (8.3%)	n.a.
Ventricular dilatation[c] – n (%)	17 (70.8%)	n.a.
Yes, mild – n (%)	9 (37.5%)	n.a.
Yes, moderate – n (%)	8 (33,3%)	n.a.
Yes, severe – n (%)	0 (0%)	
Punctate cerebral lesions[c] – n (%)	3 (12.5%)	n.a.
Delayed myelination[c] – n (%)	3 (12.5%)	n.a.
Bayley Scales of Infant Development II at 2 yrs corrected age		
MDI – median (range)/unknown	101 (80–122)/2	n.d.
PDI – median (range)/unknown	95 (72–125)/8	n.d.

yrs = years; d = days; AIS = amnion infection syndrome; APGAR = method to score the postnatal adaptation of a newborn; TEA = term equivalent age; n = number; n.a. = not applicable; n.d. = not done.

[a] The German school system has three levels of graduation. Level III qualifies for university entrance and Level 0 represents no graduation.

[b] Intraventricular hemorrhage was graded according to Papile et al. [42].

[c] White matter injury (ventricular dilatation, punctate or cystic lesions and delayed myelination) were graded according to Kidokoro et al. [43].