cogent psychology

DEVELOPMENTAL PSYCHOLOGY | RESEARCH ARTICLE

Spontaneous eye-blinking rate from pre-term to six-months

Emmanuel Descroix[1,2,3]*, Marie Charavel[1,4], Wojciech Świątkowski[5] and Christian Graff[1,2,3]

*Corresponding author: Emmanuel Descroix, Université Pierre Mendès France, Grenoble Alpes University, Grenoble, France; CNRS UMR5105, Laboratoire de Psychologie et Neurocognition, Grenoble, France; Psychology Department, Centre de Biologie du Comportement, 1251, avenue centrale, BP 47X, 38400 Grenoble Cedex 9, France
E-mails: Emmanuel.Descroix@upmf-grenoble.fr; emmanuel.descroix@yahoo.fr

Abstract: Little is known about the development of eye blinking, a spontaneous activity mediated by dopamine, from the period in utero to six months after birth. We evaluated spontaneous eye blinking rates (SBR) for 11 full-term and 11 premature infants with their mothers. Dyads were videotaped during bottle-feeding in natural context: at birth, at term (for premature infants), three months, and six months after term. Infants' and mothers' blinks were counted in a double-blind procedure.Premature infants blinked over six times more than fetuses of similar maturational age recorded in utero in the previous literature. SBR (around two blinks per minute) show no visible increase over the next six months, and no difference between the pre-term and typical groups. Infants' rates contrasted with those of their mothers (around five blinks per minute) who were thus recorded under the same conditions.Our longitudinal and ecological record confirms previous results showing low blinking rates of infants before one year. It illustrates the importance of delivery in the expression of a spontaneous behavior. It defines the typical early stage of a behavior that develops later in relation with the dopaminergic system and speech.

Subjects: Neonates; Ophthalmology; Pediatric Nursing; Perinatal & Neonatal Medicine; Physiology

Keywords: spontaneous eye blink (SEB); spontaneous eye blinking rate (SBR); prematurity; point rhythm; premature; delivery; post-natal behavior; dopamine

ABOUT THE AUTHOR

Emmanuel Descroix has been interested for the past 10 years in nonverbal communication, exploring it and teaching it the context of business interpersonal communication. To explore embodied cognition and action/perception models, he has engaged in an academic research program, conducting a PhD thesis in cognitive sciences at Grenoble Alpes University in France.

Emmanuel Descroix

PUBLIC INTEREST STATEMENT

Once they are born, young infants start blinking six times as much as they earlier did in their mother's womb, whether term or premature. Spontaneous eye-blinking is related to the function of cleaning and lubricating the eye, but it is only one among others. Adults' blinking rate depends considerably on mental and emotional states. Scientists increasingly relate spontaneous eye-blinking with speech communication. Tracking blinking rate changes during infancy could help to detect early developmental disorders linked to the neurotransmitter dopamine. To start with, research conducted in everyday conditions (while nursing) shows that in the first six months of their life, healthy infants blink not even half as much as their mothers.

cogent • oa

1. Introduction

Our eyes blink differently according to both context and age. Several types of blinking may be distinguished (Doane, 1980; Kaneko & Sakamoto, 1999; Leemann, 2004). The *voluntary blink* is conscious. The *blink reflex* mechanically protects eyes from any impact. The *neuromotor blink* is associated with head movement onset. Finally, the *spontaneous eye blink* (SEB), the object of the present study, contributes to more than to the primary function of humidifying the cornea with a uniform tear film (Doane, 1980; Zaman, Doughty, & Button, 1998). Indeed, the Spontaneous eye blinking rate (SBR) is strongly modulated by the context, by emotion, and cognitive factors (Cruz, Garcia, Pinto, & Cechetti, 2011), it especially increases during conversation (Bentivoglio et al., 1997; Freudenthaler, Neuf, Kadner, & Schlote, 2003; Karson et al., 1981; Ponder & Kennedy, 1927). SEB is clearly mediated by the dopaminergic system (DS) (Karson, 1983; Karson, Burns, LeWitt, Foster, & Newman, 1984; Slagter, Georgopoulou, & Frank, 2015; Slagter et al., 2012). Dopamine levels have been related with SEB rates (Taylor et al., 1999). Hence, abnormal SBR can orient the diagnosis toward DS dysfunction impacting cognition and behavior (Dreisbach et al., 2005; Müller et al., 2007). Various adult pathologies involving DS are marked by SBR changes. For example, SBR is much faster in Gilles de la Tourette syndrome (Cohen, Detlor, Young, & Shaywitz, 1980), in schizophrenia (Karson, Dykman, & Paige, 1990; Mackert, Woyth, Flechtner, & Volz, 1990), and in dystonia (Deuschl & Goddemeier, 1998), whereas it decreases in Parkinson syndrome (Deuschl & Goddemeier, 1998; Esteban, Traba, & Prieto, 2004) and in ADHD (Konrad, Gauggel, & Schurek, 2003) for instance. DS underlies fine motor adjustment (Semmes, 1968; Tucker & Williamson, 1984) and therefore determines verbal production and interaction (Pell & Monetta, 2008).

In utero (human fetuses between 33 and 42 weeks postconceptional age), eyes blink only a few times per hour (Petrikovsky, Kaplan, & Holsten, 2003). In the first year after birth, when awake, infants blink several times per minute (Zametkin, Stevens, & Pittman, 1979). In children, the SEB curve grows and reaches a plateau in adolescents (Leemann, 2004). Adults in the resting baseline condition blink around 20 times per minute (Karson et al., 1981; Leemann, 2004), but the cognitive context widely inhibits or activates the process.

Diverse studies suggest that the increase in SBR is already initiated during the first months. The pre-ocular film of tear that is concerned by the SEB's wiping role changes in the first weeks after birth, and even more so in premature newborn infants (Toker, Yenice, Öğüt, Akman, & Özek, 2002). However, the transformation of the young infants' peripheral ophthalmic system may be less crucial in SBR changes than the development of the DS that mediates cognitive functions, such as those involved in speech interaction (Bacher, 2010; Lawrenson, Birhah, & Murphy, 2005; Zaman et al., 1998). The present study aims at tracking the profile of SBR changes before six months. A better knowledge of typical SBR in the early stages of infant development may contribute to tracking troubles affecting DS and eventual speech behavior as soon as possible. Additionally, because SEB in premature infants has not been documented yet, data on this population may give hints on the development of perinatal DS, and milestones on normality in a quantifiable behavior for this population.

So far, the main quantitative results at hand are detailed as follows (Figure 1). In fetuses, SBR remains as low as .103 SEB per minute (SBM), rising to .255 SBM in a context of vibroacoustic stimulation (Petrikovsky et al., 2003). From birth to four months, infants blink on average at 2 SBM; the rate increases to 3 SBM between four and eight months, and reaches 5 SBM between eight and twelve months (Lawrenson et al., 2005); the latter results were obtained using a continuous airflow directed to the eyes; they were complemented by two independent studies that additionally illustrate how context modulates the rate. Three-month-old infants averaged 2.6 SBM before and after feeding, but increased to 3.5 SBM during feeding, and up to 5 SBM when stimulated (Bacher & Smotherman, 2004b). Between four months and one year, SBR increases from around 3.3 to 4.1 SBM; these rates obtained in baseline condition were decreased at four months by exposition to colorful toys, but not by an experimenter's facial expressions and vocalizations (Bacher, 2014).

cogent •• psychology

Figure 1. SEB progression according to the current literature.

Notes: X-axis: age in months. Y-axis: SBR in blinks per minute (sample average). Squares: sampling by average age. Horizontal rectangles: sampling by age range. Lines connect sample data within longitudinal studies. Vertical arrows: age sampling in the present study. From left to right: gray rectangle, Petrikovsky et al. (2003); black square, (Mantelli et al., 2007); three large white rectangles, Lawrenson et al. (2005); three horizontally striped rectangles, Bacher and Smotherman (2004b); six textured squares, solid lines, Fowler (2011); one gridded rectangle, Bacher and Allen (2009); four diamonds, dotted lines, Bacher (2014).
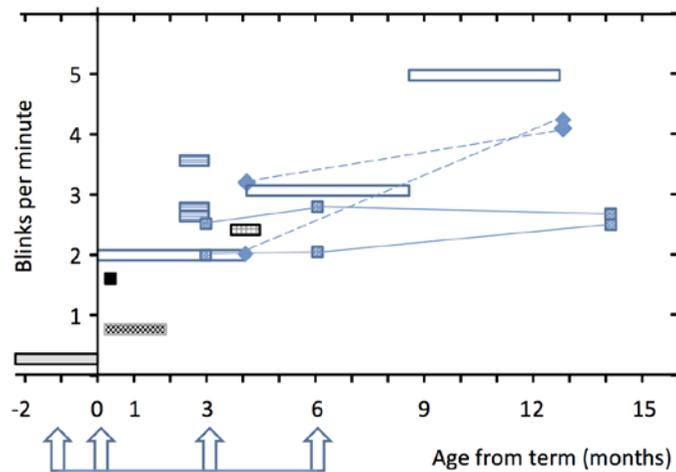
We propose to clarify the early increase in SBR by a longitudinal study, starting before predicted birth age. Spontaneous—not reflex—blinking remains to be documented in the premature infant. Does delivery—even when it occurs before term age—activate blinking development that remains dormant in utero? How do post-natal maturation and/or experience differentiate premature infants from typical infants at both birth and term age? Does their SBR increase before six months, and how? We explored SEB in pre-term and full-term infants videotaped with their mothers at nursing time. The body of records displayed the same individuals at birth, term, three, and six months after term, in an ecological context: the clinic room for the first record, then at home. Additionally, mothers presented themselves as adult controls in the same context. To our knowledge, this study is the first attempt to compare longitudinally the SEB in premature and term-born infants before 6 months.

2. Method

2.1. Participants and recording

Twenty-two mother/infant dyads were selected from a corpus of 30 for complete longitudinal records from birth to six months after term (Table 1). Eleven infants were full-term, with typical birth-weight (*Typical* dyad group). The other 11 were born before term, with pregnancy age 27–34 weeks (*Premature* dyad group) calculated according to the WHO criteria. The mothers' age at delivery was similar in both groups. Typical and premature dyads were sampled from the same population. In both groups, all the participants were Caucasian, and most mothers were either employees or managers. They had been recruited directly from one maternity ward and two neonatal units in Lyon (France).

Mother–child dyads were filmed at bottle-nursing time. Mothers gave the bottle to the infants, talked, soothed, burped them, etc. Infants usually suckled and interrupted feeding several times during a recording session. We took advantage of video recordings that had been performed for an initial behavioral study on prematurity (Charavel, 2000), hence neither the participants nor the cameraman were aware of the later investigators' interest in blinking.

Each dyad was recorded longitudinally, with one video session for each age (Figure 2). For typical, i.e. term-birth infant dyads: as soon as possible after birth (*birth* session), three months after birth (*three-month* session), and six months after birth (*six-month* session). For premature infant dyads, the dyad was first recorded after the infant was able to feed by suckling (*birth* session), at theoretical term date (42nd pregnancy week, *term* session), three months after theoretical term (*three-month* session), six months after theoretical term (*six-month* session). Thus, premature dyads appeared in four sessions, typical dyads in three sessions only.

Table 1. Features of sampled dyads			
		Premature	**Typical**
	Sample size (boys:girls)	6:5	4:7
	Mother's socioeconomic status	Middle or upper	Middle or upper
	Mother's age $M \pm SD$ (years)	30 ± 4	33 ± 5
	Newborn's rank among siblings (1st, 2nd, 3rd, 4th)	(4, 6, 0, 1)	(6, 4, 0, 1)
	Pregnancy age $M \pm SD$ (weeks)	30.2 ± 2.5	42 ± 1
	Birth weight $M \pm SD$ (KG)	1.35 ± .18	3.37 ± .41
	Weight at birth session	2.04 ± 2.03	3.12 ± .25
	Weight at term session	3.26 ± .51	
	Age at birth session (days)	51.5 ± 9.3	5.1 ± 1.7
	Age at term session	76.0 ± 74.8	
3-month session	Actual age from birth	164.8 ± 29.5	85.1 ± 4.6
	Theoretical age from term	88.8 ± 16.9	
6-month session	Actual age from birth	249.4 ± 23.3	176.6 ± 8.2
	Theoretical age from term	173.4 ± 10.4	
	Pathologies before six months	None	None

Notes: When they do not differ, units between parentheses are valid for items listed in the subsequent lines. Birth- and term- sessions and ages differ for premature infants but they are the same for normal infants. Many normal newborn lose some weight in the first days between birth and recording.

Figure 2. Sampling schedule and comparisons.

Notes: Numbering shows comparisons conducted to track specific effects. (1) Amniotic context effect: blinking before term (for comparison with fetus). (2) Gestational age effect: normal newborn vs. premature new-born. (3) Post-natal experience context effect: new-born vs. older infant of the same gestational age (term). (3′) Control on [gestational age * post-natal] combined effects. (4) General premature-delivery effect: typical vs. premature infant (along ages). (5) and (5′). General age effect from birth to six months in typical and in premature infants. (6) Infancy (not represented): infant vs. mother (along ages).
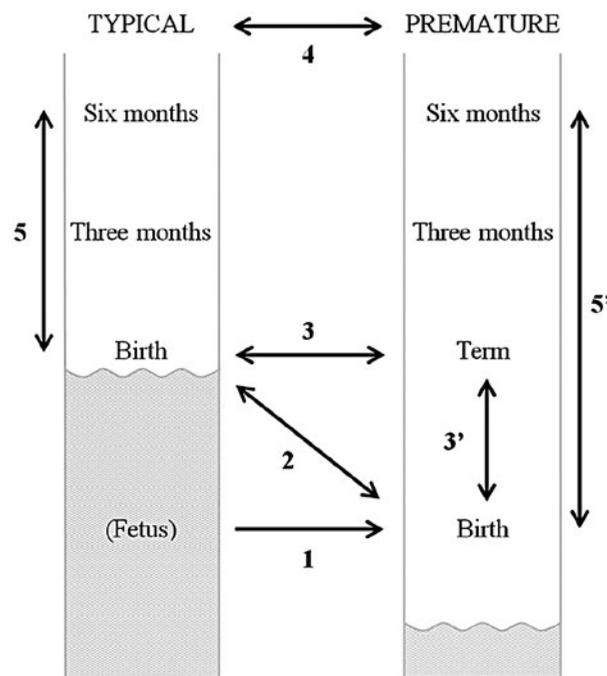
The birth session—and also the term session for one premature dyad only—took place in a clinic, all the others at the participants' homes. Before the dyad arrived in the room, the microphone was elevated and the camera was set up on a tripod two to three meters in front of the nursing seat. The mothers, who were sitting on a bed, in an armchair, or on a couch, were asked to behave as usual. Once the dyad was installed, framing was adjusted to include the entire child and at least the

Figure 3. Frame examples extracted from one 7-session block (out of 11 blocks).

Notes: N°1/7, Premature infant girl at birth; both mother's and infant's eyes are open and visible for counting. N°2/7, Typical infant girl at three months; mother's eyes open usable for counting, but infant's eyes closed thus not countable. N°3/7, Typical infant girl at six months; both mother's and infant's eyes open thus countable. N°4/7, Premature boy at three months; mother's and infant's eyes open and countable. N°5/7, Typical boy infant at birth; mother's and infant's eyes open and countable. N°6/7, Premature boy at three months; mother's and infant's eyes open and countable. N°7/7, Premature infant girl at term age; mother's and infant's eyes open and countable.

mother's chest and head. Recording conditions were as ecological as possible. Unfortunately, blinks were not visible throughout the recorded sessions as in ideal experimental conditions. The infant could sleep, cry, have his/her head too down or turned aside … Consequently, usable sequences had first to be defined, before blinks could be counted in them (Figure 3).

2.2. Procedure of data collection

2.2.1. Staff and instructions
Ten volunteer appointees were recruited among undergraduate psychology students. They received instructions defining SEB. They operated in pairs separated into two teams, *sequencers* and *counters*.

The s*equencers* selected and time-stamped usable sequences in which blinking could be counted. They had to keep only the sequences during which the eyes of mothers and infants were visible and open. Blinking activity was taken into account not only while the infant was suckling, but also during feeding pauses, provided the participant had open eyes. Views in which the mother was speaking were discarded because speaking usually increases SBR (Karson et al., 1981).

The counters counted the SEB in these usable, time-stamped sequences. In order to avoid debatable scoring linked to subtle variations in SEB, they scored a SEB when the eyelid rapidly fell down, closed the eye, and lifted up immediately. They discarded eye-closing which lasted more than six frames (> 1/3 s), reflex blinks associated with sudden stimuli, and neuromotor blinks associated with movements: coughs, yawns, startles, grimace (Bacher & Smotherman, 2004b; Charbonnier & Blanchi, 1995; Kaneko & Sakamoto, 1999; Stern, Walrath, & Goldstein, 1984). Our criteria may be used by any practitioner in the field. To test for both sequencers' and counters' reliability, each of the two counter teams, operating on the same sessions but prepared by a different sequencer team, respectively, yielded final scores (square-rooted SBR) to be compared. The linear correlation between counters computed on seven sessions was satisfactory for the infants' scores (Pearson's $r(5) = .926$, $p < .01$), and for the pooled infants' and mother's scores (Pearson's $r(12) = .915$, $p < .0001$) as well.

2.2.2. Randomization of raw data for assignment
To avoid any expectation effect, appointees ignored all independent variables and how they were distributed in the sampling procedure. Therefore, they could not expect any progression with age, nor compare typical with premature infants. Only a concern for mother-/infant difference could be suspected. Appointees were assigned semi-randomized balanced blocks of sessions, mixing ages, and dyads (Figure 3). Two sessions of the same dyad were processed separated by at least 10 other

cogent ·· psychology

sessions and a minimum lapse of one week. Sessions were distributed in 11 blocks. Each block included seven sessions: four different premature dyads at four different ages, respectively; three different typical dyads at three different ages, respectively.

All the 77 sessions (3 sessions * 11 typical dyads plus 4 sessions * 11 premature-born dyads) were exploited, unless defective, thus totalizing over 53 h of video. Appointees used the frame-to-frame adjustment wheel of a videocassette recorder (Smart Engine, Sony) connected to a 14-inch screen (Philips FlatTV) with a 25fps- resolution, i.e. 40 ms between successive frames.

2.2.3. Time-stamping of usable sequences

The sequencers operated in pairs. They referenced the time stamps, visible on the video display, to define the beginning and the end of each relevant, usable sequence. They listed them to define all sequences in which SEB could be counted for at least four seconds. They scanned each session twice: first to select usable sequences for counting the infant's SEB, and second for the mother's. The order—either mother or infant scanned first—was alternated from session to session. Each session yielded one sequence list for the infant and one for the mother.

2.2.4. Randomized selection of sequences to be counted

For each session, counting was limited to 300-s cumulative samples. Sampling started with randomly picking one usable sequence within the session's list, and continued with the following sequences (chronological order). Each sequence's duration was added to the preceding ones, until reaching to a maximum of 300 s, or to the bottom of the list. In the latter case, the addition continued starting from the top of the list and ended either before the first picked sequence, or at the 300-s maximum duration. The length of each session's list varied in both quantity of usable sequences and in total duration sequences, because it depended on the participant's position and activity (e.g. sleeping, speaking). With respect to total recording time, the percentage duration during which infants' SEBs were visible represented 63%, reaching 60% for mothers. Among 77 sessions, 71 could be exploited (six were defective) but 5 of them cumulated less than 300 s of sequences. The mean cumulative sequence duration per session was $M = 777$ s with a standard deviation SD = 422 s in general; for sessions that did not cumulate 300 s of sequences, it was $M = 147$ s with standard deviation SD = 113 s. The list extract (with start and end timestamps of each selected sequence) was passed on to the counters.

2.2.5. Counting SEB in selected sequences

Each selected sequence was viewed silently, so that both counters within a pair counted the blinks independently. If counters did not agree at the end of the sequence, counting started over again.

At the end of the process of data sampling and counting, none of the sequencers or counters had guessed any of the hypotheses (see Figure 2). They could not keep track of individuals, because they focused on the eyes only, because mothers' and infants' appearance (clothing, hair ...) changed significantly between two sessions, and because a long period of time and a large number of different sessions separated two viewings of the same individual. In addition, different sessions of the same participant were processed by different sequencers and different counters. This ruled out any expectation bias. Operating by pair reduced individual judgment variability between appointees.

2.3. Overview of the analyses

For each session, the total SEB count of usable sequences was divided by their total duration in seconds (then multiplied by 60 in order to yield an SBR score in SBM). A series of analyses of variance was performed on the SBR to test the following effects: the effect of age, between pre-term and typical infants, and also to compare infants paired with mothers.

Out of 77 filmed sessions, six could not be processed because the tapes were damaged. One preterm infant presented an outlier score (33.5 SBM) contrasting with other pre-term infants at the same age ($M = 1.72$, SD = 1.4), and therefore was dropped from the subsequent analyses because of

an uncommon studentized deleted residual (McClelland, 2000). The data did not comply with normal distribution; they were therefore prepared for inferential statistics by square-root transform, not log-transform, because of null-counts. For descriptive statistics, regular (arithmetic) mean and standard deviations were computed from raw data.

Analyses may be recapitulated in six main steps as displayed in Figure 2.

First, the post-delivery (vs. ante-delivery) *context* alone may allow or arouse blinking; the SBR statistics of premature infants *after* birth were computed, to be matched with data on fetuses (i.e. *before* birth) at similar gestational age (Petrikovsky et al., 2003).

Second, blinking may increase from perinatal maturation alone; premature newborns were compared with typical newborns, therefore at different maturational *ages* but in the same early postnatal context (both shortly after birth).

Third, postnatal *experience* may play a role (in addition to maturation) in the first weeks. Thus, the premature infants at the age of theoretical term, having already lived several weeks ex utero, were compared with typical newborns at term, hence both at the same maturational age. In addition, postnatal experience may combine with maturation. An SBR change was therefore tested in premature infants between birth and term age, which could be due to both maturational change and experience.

Fourth, premature infants' *early delivery* may leave longer lasting effects. SBR scores of typical and premature infants were compared from birth to six months.

Fifth, the *profile* of SBR change was tested along the three different maturational ages. Both typical and premature samples were investigated (because perinatal circumstances show no direct or interactional effects).

Sixth, infant's scores were paired/compared with their mothers' to assess the general, well-known question of low blinking in infants, taking advantage of a common experimental-ecological context.

Since multiple comparisons were required for the above-mentioned analyses, we adjusted the traditional .05 alpha threshold according with the Bonferroni adjustment. Therefore, for the following statistical analyses, we used .0083 as the adjusted alpha threshold.[1]

3. Results
Results are listed according to the steps numbered in Figure 1, between parentheses in the subtitles, and partly displayed in Figure 4.

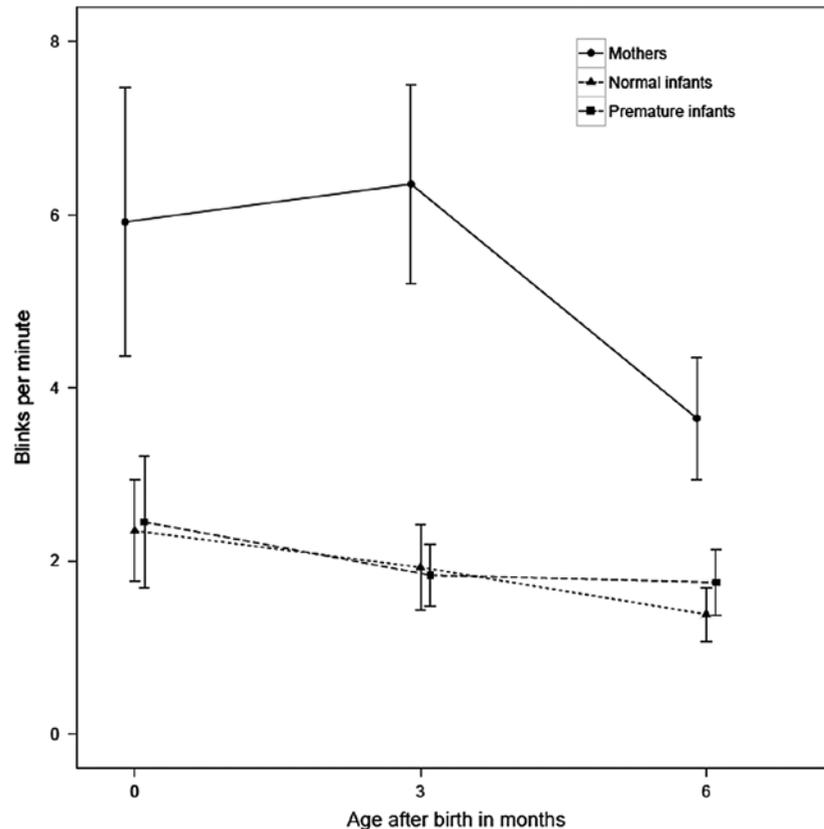#### 3.1. SBR difference between premature infants and fetus (1)
We compared the premature infant's SBR at birth ($M = 1.72 \pm 1.41$, *min* = .2, *max* = 4.4 SBM) with two fetuses' SBR values reported in Petrikovsky et al. (2003): the SBR of fetuses at calm state ($M = .103$) and the SBR of stimulated fetuses ($M = .255$). Hence, we performed two Student *t*-test against a fixed value (two fetuses' SBR values). According to the *t*-tests, premature infants' SBR at birth differed from the one reported on fetuses' who were calm ($t(9) = 4.77$, $p < .001$, $\eta^2 = .74$) and from the one of stimulated fetuses $t(9) = 3.78$, $p < .005$, $\eta^2 = .64$).

3.2. SBR difference between premature infants at birth and term-born infants at birth (2)
No reliable difference was found using a one-way ANOVA comparing the SBR of premature infants at birth ($M = 1.72 \pm 1.41$; *min* = .2, *max* = 4.4) with the SBR of term-born infants at birth ($M = 2.35 \pm 1.95$; *min* = 0, *max* = 6.9), ($F(1,18) = .36$, $p = .56$, $\eta^2 = .02$).

cogent ·· psychology

Figure 4. SBR of infants and mothers during nursing time.

Notes: Mean and standard error for each age class for premature infants (*N* = 11), typical infants (*N* = 11) and mothers (*N* = 22). Only the mother vs. infant rate difference is significant. The apparent drop in mothers' blinking rate from three to six months is not statistically significant.

3.3. SBR difference between premature infants at theoretical birth and typical infants at birth (3)

The blinking rate of premature infants at theoretical birth age (*M* = 2.45 ± 2.39; *min* = 0, *max* = 6.4) was not statistically different from the blinking rate of term-born infants at birth (*M* = 2.35 ± 1.95; *min* = 0, *max* = 6.9) according to a one-way ANOVA ($F_{(1,18)}$ = .33, *p* = .57, η^2 = .02).

3.4. SBR difference between premature infants at birth and at theoretical birth (3′)

The premature infants' SBR at the moment of their actual birth (*M* = 1.72 ± 1.41; *min* = .2, *max* = 4.4) was not significantly different from their SBR at the time of their theoretical age (*M* = 2.45 ± 2.39; *min* = 0, *max* = 6.4) according to a repeated measures ANOVA conducted with two missing values of one premature infant ($F_{(1,8)}$ = .29, *p* = .60, η^2 = .03).

3.5. Effect of age and SBR difference between premature and typical infants during the six months following birth (4, 5)

We tested whether the age stage had an effect on SBR evolution, and whether the infant type (premature vs. term-born) potentially moderated this effect. Thus, we performed a mixed ANOVA, taking the infants' SBR at each of the three stages as a within-subject factor (birth, three months and six months), and the type of the infant (premature vs. term-born) as a between-subject factor. The premature infants' SBR at birth was averaged across their SBRs at their actual and theoretical birth stages, because we detected no significant difference between the two. Our analysis among 77 sessions was conducted with 6 missing values, 3 of premature and 3 of typical infants, and 1 excluded value that exceeded 10 fold the others' average. It yielded no reliable effect of age stage ($F_{(2,28)}$ = .22, *p* = .80, η^2 = .01). The infant type did not visibly moderate the SBR evolution across age stages ($F_{(2,26)}$ = .57, *p* = .57, η^2 = .04).

3.6. SBR difference between infants and mothers (6)

Finally, we tested whether the infants' SBR (both premature and term-born) differed globally from the SBR of their mothers on the whole of three age stages. Therefore, we computed an average score for each subject, and tested whether it varied between infants and mothers. Considering that no significant differences had been found between the premature infants' SBR and the term-born infants SBR in previous analyses, we excluded this factor in the following test. In the same vein, because no significant difference has been detected between the premature infants' SBR at their actual birth and their theoretical term, these two scores were averaged for the following test. Hence, the one-way ANOVA yielded a significant effect of the group type (i.e. mother vs. infant) on the SBR average ($F(1,41) = 15.93$, $p < .0003$, $\eta^2 = .28$), indicating that on the whole, infants blinked less than their mothers.

4. Discussion

This study of the development of spontaneous blinking is the first longitudinal focus on the first six months after term. It includes premature infants recorded both before normal-delivery age and later. The low SBR of infants—measured so far in laboratory environment—was confirmed in an ecological context, by comparing them with adults recorded simultaneously under identical conditions. Results may provide a basis to characterize troubles affecting the DS or other structures involved in later speech behavior.

Premature infants before term blinked much more than fetuses even at the same maturational age according to Petrikovsky et al. (2003). They showed no visible progression, neither when reaching the age of normal birth, nor afterwards. Both premature infants and term-born infants were similar in this regard across the six months following birth age, whether expected or actual. SBR of all infants always remained lower than their mothers'. Despite a relatively small sample size, these results constitute a genuine contribution because longitudinal studies carried out on neonates including premature infants are difficult to conduct. Detailed by steps listed in this paper's previous sections (Figure 1), our investigation led, respectively, to the following quantitative findings:

(1) Premature newborns spontaneously blinked over six times more than fetuses, even when the latter were stimulated (Petrikovsky et al., 2003). The comparison neatly controls for age, because the post-conceptional age range of our pre-term infants was within that of the fetuses used in the match ([35.3; 39.8] vs. [33; 42] weeks, respectively).

(2) Premature infants before term blinked at a similar rate to their typical counterparts who were over five weeks older in gestational age. The shorter vs. longer time they had spent maturing in utero was not reflected in SEB after they have been through delivery and experienced some early post-natal life.

(3) At term age, premature and typical infants still blinked at a similar rate. Yet premature infants had already lived for more than 11 weeks (76.0 ± 19.7 days) ex utero, whereas typical infants had only experienced less than one week (5.1 ± 1.7 days) of ex utero life. Their different histories did not, therefore, reveal a major effect of experiencing post-natal context.

(3′) Likewise, premature infants' scores did not show any noteworthy change between the first recording after birth, when they had actually experienced seven weeks of extra-uterine life (50.8 ± 9.1; *min* = 36, *max* = 67 days), and the second recording, at theoretical term, when they had lived almost 11 weeks (76.0 ± 19.7; *min* = 49, *max* = 108 days) ex utero. The difference of four more weeks of extra-uterine life (24.5 ± 15; *min* = 3, *max* = 47 days) did not visibly impact on their SBR.

(4) Premature infants blinked at a rate similar to typical ones throughout the six first months of life. Therefore, in the long term, the premature delivery (or conditions associated with it) did not induce visible permanent dissimilarities over this period.

(5) SBR scores of both premature and typical infants did not show any progress with age. Their average SBR, close to 2 SBM, fits well with those of previous literature (Bacher & Smotherman, 2004a; Cruz et al., 2011), that shows high inter-study variability.

(6) Infants blinked significantly less than their mothers, while being in the same ecological conditions. The low SBR of infants before six months was thus well assessed by the comparison. Nevertheless, the mothers' rates (5.2 SBM) were unexpectedly low, given the values generally reported in the literature. Compared with other adults in laboratory conditions, they match people in mental concentration (such as when reading, 4.5 SBM) rather than people in baseline conditions (rest, 18.0 SBM) or in conversation (26.7 SBM) (Bentivoglio et al., 1997).

4.1. Difference between premature before-term and fetus

Fetuses' low SBR (Petrikovsky et al., 2003) is likely to be due to their intra-uterine conditions, not to a lack of maturation with regard to their young gestational age per se. The liquid vs. atmospheric medium, the umbilical vs. bottle nourishment, and many other factors can be invoked. Importantly, a rise in the general level of stimuli cannot fully account for this difference: stimulated fetuses also present an increase in SBR, but at a level still far below the infants' SBR reported in our study.

It is also possible that the actual event of delivery, and/or the first moments after birth, initiates physiological mechanisms that were already in place for several weeks or months but needed some trigger to operate. Recordings of the first hours after birth are however missing to know exactly how SBR reaches the level that we measured from the first recording after birth. In fact, the birth sessions took place at least three days after delivery in typical infants and even weeks later in premature infants.

Comparable to the *foramen ovale* closing at birth that sets up vascular circuits definitely, postnatal activating of blinking networks define SBR levels that are maintained for the following weeks or months. Even later within the first year of life, further effects of maturation are hardly assessable contrary to cognitive and social effects in the same laboratory conditions (Bacher, 2014; Fowler, 2011). This lack of development in the infant's blinking activity contrasts with the host of behavioral and physiological parameters that change drastically across these ages. Specifically, the tear production substantially increases during the perinatal period and correlates with maturation (Toker et al., 2002); because tears are wiped by eyelid movements, SBR could be expected to change consequently, but it does not.

4.2. Low SBR in infants and their mothers

Infants blinked much more than fetuses, yet they blinked much less than their mothers, their adult controls in the same physical environment. Infants' SBR was actually considerably lower than adults' in general, considering that their mothers' rates were also quite low with respect to other adults recorded in various conditions.

In fact, the mother's SBR during feeding closely resembles that of experimental participants in a concentrated mental state (Holland & Tarlow, 1972; Ponder & Kennedy, 1927; Stern et al., 1984). In this condition, adult SEB seems to be inhibited, because it is lower than baseline whereas various other tasks (speaking, learning) boost it. A similar inhibition cannot explain infants' low SBR during feeding because they blink normally more at this moment than before or after it (Bacher & Smotherman, 2004b).

Because SEB is involved in adult interpersonal communication (Bentivoglio et al., 1997; Freudenthaler et al., 2003; Karson et al., 1981; Ponder & Kennedy, 1927), one may expect some correlation between mother and infant SBRs, which would objectively illustrate the mother–infant bond. We did plot mothers' with infants' session scores, but found no general correlation over the whole set of data; there is none neither when separating term—and premature—infants, nor when grouping data for the same stage only. Finally, a regression on the session rank along stages (1st to

4th higher SBR among each premature dyad's four sessions and 1st to 3rd in typical dyads) did not show any linear—or even second-order (quadratic)—trend in regression analysis linking mothers' and infants' SBR rank. It may be noticed that we do not as yet know of such correlation investigated in other dyads, such as, e.g. between two adults in conversation.

4.3. Age and situation changes

The literature only barely suggests SBR increases before one year (Bacher, 2014; Fowler, 2011). Our data show no early signs of higher rates projected beyond six months, but at 2 SBM, they remain in accordance with established ranges in general, notwithstanding the fact that lower rates (.7 SBM) have been reported before two months under laboratory conditions (Zametkin et al., 1979) and higher rates have been reported before three months, especially during feeding (3.7 SBM, Bacher & Smotherman, 2004b). The sameness of SBRs in our various records may seem imprecise, but even with a limited sample size we consider it as an accurate result yielded by our methodology. Our definition of SEB can be easily understood and applied. Making judges operate by pairs reduced measure variability from individual, subjective and attention effects. Contrariwise, measure variability may have expanded from giving different appointees the task of measuring the same infant at different stages, as well as measuring the same stage on different infants. This may explain the lack of visible effect. However, the procedure kept them unaware of these variables as well as of prematurity, a blind procedure that guarantees against any expectation biases.

Of course, this reliability may have been imposed at the risk of missing some putative subtle effect. However, given the lack of perceptible trend, we would not expect a significant one to emerge from a standardized field study of the same age classes, even with a larger sample or with another objective scoring method that would be relevant to the practitioner.

We also consider unlikely that an expected SBR progress with age would be visible in some other situation or at some other important moment of the day. Six-month old infants may have other moments of alertness where SBR may change with age. However, a longitudinal study dictates some homogeneity in sequence sampling. Maintaining the same conditions, starting from before term, was a requisite to prevent from confounding variables that link context and maturation. During early infancy, nursing is a unique period for recording an infant in typical life. It offers the optimal state of alertness, between crying and sleeping, in a repeated situation. Unfortunately, because it is also a context of variability in terms of activities, a change of SEB linked to one specific activity may be buried by the overall variability. Yet our methodology was effective enough to reveal infant–mother differences and the relatively low rate of nursing mothers by comparison to adults in laboratory conditions. To be realistic, quite extraordinary means would be required for conducting a thorough longitudinal behavioral field study focusing either on a more specific standard situation or on a more definite behavior, which would be applicable at six months and at birth as well.

Long ago, Ponder and Kennedy (1927) stated that "true blinks first make their appearance about the age of six months". Indeed, the levels of magnitude in adult SBR vs. in infant SBR suggest that adults emit other or supplementary SEBs. The factors that determine increases in adult SEB, involving DS modulation (Goldberg, Maltz, Bow, Karson, & Leleszi, 1987; Karson, 1983) also demonstrated in animal models (Jutkiewicz & Bergman, 2004; Kleven & Koek, 1996) would act only later in human infants. Actually, the left hemisphere, the richer one in dopamine (Glick, Ross, & Hough, 1982; Tucker, 1981), develops slower than the right one during the first year after birth (Chiron et al., 1997; Scheibel et al., 1985; Toga & Thompson, 2003). This substantiates the lack of visible change during the period of our investigation.

The infant blink duration (419 ± 89 ms, Bacher & Smotherman, 2004a) is longer than adult SEB (150–250 ms, Charbonnier & Blanchi, 1995; Chételat-Pelé, 2010; Kaneko & Sakamoto, 1999). Wiping eye blinks present at birth may later be mixed with other spontaneous blinks related to other mechanisms or functions. Controlled laboratory conditions may reveal fine differences in duration and

amplitude of upper- and lower eye-lid movements. But such criteria may be hardly usable for field-work, thus overall SBR will long remain the most convenient marker.

Another explanation would be that some systems that normally stimulate SEB are already mature, but they are not activated in the situation. The nursing context—not only the physiology of the first months of life—involves cognitive and behavioral activities that are specific or limited. The maturation—context conditions are similar for both pre-term infants and infants born at term thus it leaves them with similarly low blinking behaviors. Mothers themselves show during nursing a SBR that is lower than adults in general. The SBR of adults recorded in laboratory conditions may be related to functions that are latent or absent in young infants. For instance, in normal adults, most changes are observed during conversation, a communication mode that is not that of the nursing dyad. SEB associated with language, a function that is mainly implemented by the left hemisphere, only emerges much later than at six months. Because DS plays a role in speech fine movements (Semmes, 1968), SBR may add to markers of language acquisition insofar as SEB offers access to DS activity. We propose to focus the assessment of SBR changes over the essential periods of speech onset. The baseline may prepare for the diagnosis of language-related developmental disorders.

5. Conclusion

The dramatic SBR difference between premature infants observed before term and fetuses of similar post-fecundation age is more attributable to post-natal *vs.* pre-natal milieu than to maturation time. Infants' very low SBR level is confirmed in the field by comparison with adults in the same natural conditions. After term, our six-month longitudinal study does not show any remarkable progress and does not suggest any late effect of premature delivery. As for their mothers, other contexts may disclose latent mechanisms, and more maturation will allow new functions such as verbal language to increase SEB variability. Insofar SBR reflects DS that is involved in language, very significant changes in SBR are expected when the child starts speaking.

Author details

Emmanuel Descroix[1,2,3]
E-mails: Emmanuel.Descroix@upmf-grenoble.fr; emmanuel.descroix@yahoo.fr
Marie Charavel[1,4]
E-mail: Marie.Charavel@upmf-grenoble.fr
Wojciech Świątkowski[5]
E-mail: Wojciech.Swiatkowski@unil.ch
Christian Graff[1,2,3]
E-mail: Christian.Graff@upmf-grenoble.fr
[1] Université Pierre Mendès France, Grenoble Alpes University, Grenoble, France.
[2] CNRS UMR5105, Laboratoire de Psychologie et Neurocognition, Grenoble, France.
[3] Psychology Department, Centre de Biologie du Comportement, 1251, avenue centrale, BP 47X, 38400 Grenoble Cedex 9, France.
[4] Laboratoire Inter-universitaire de Psychologie LIP/PC2S EA4105, Université Pierre Mendès France, Grenoble Alpes University, Grenoble, France.
[5] Social Psychology Department, University of Lausanne, Lausanne, Switzerland.

Note

1. We divided .05 by the number of between-subjects comparisons (6 comparisons). Since within-subjects comparisons rely on models that involve their own error terms (i.e. the comparisons are independent), we did not include them into the adjustment.

References

Bacher, L. F. (2010). Factors regulating eye blink rate in young infants. *Optometry and Vision Science: Official Publication of the American Academy of Optometry, 87*, 337–343. doi:10.1097/OPX.0b013e3181d951b2

Bacher, L. F. (2014). Development and manipulation of spontaneous eye blinking in the first year: Relationships to context and positive affect. *Developmental Psychobiology, 56*, 783–796. doi:10.1002/dev.21148

Bacher, L. F., & Allen, K. J. (2009). Sensitivity of the rate of spontaneous eye blinking to type of stimuli in young infants. *Developmental Psychobiology, 51*, 186–197.

Bacher, L. F., & Smotherman, W. P. (2004a). Spontaneous eye blinking in human infants: A review. *Developmental*

Psychobiology, 44, 95–102. http://dx.doi.org/10.1002/(ISSN)1098-2302

Bacher, L. F., & Smotherman, W. P. (2004b). Systematic temporal variation in the rate of spontaneous eye blinking in human infants. *Developmental Psychobiology, 44*, 140–145. doi:10.1002/dev.10159

Bentivoglio, A. R., Bressman, S. B., Cassetta, E., Carretta, D., Tonali, P., & Albanese, A. (1997). Analysis of blink rate patterns in normal subjects. *Movement Disorders, 12*, 1028–1034. doi:10.1002/mds.870120629

Charavel, M. (2000). Évolution de l'attitude des mères d'enfant prématuré et des mères d'enfant à terme en interaction avec leur bébé: une étude éthologique de la naissance à 6 mois [Evolution in the attitude of pre-term and term-born infants' mothers interacting with their baby. An ethological study from birth to six months]. *La Psychiatrie de L'enfant, 43*, 175–206.

Charbonnier, C., & Blanchi, J.-P. (1995). *La commande oculaire: Etude et validation expérimentale d'interfaces homme-machine contrôlées par la direction du regard* [Ocular command: An experimental study of man-machine interfaces controlled by gaze direction]. Grenoble. Retrieved from http://cat.inist.fr/?aModele=afficheN&cpsidt=173056

Chételat-Pelé, E. (2010). *Les gestes non manuels en Langue des Signes Française; Annotation, analyse et formalisation: Application aux mouvements des sourcils et aux clignements des yeux* [Non-manual gestures in French Sign Language. Annotation, analysis and formalization applied to eyebrow moving and eye blinking]. Université de Provence-Aix-Marseille I. Retrieved from http://tel.archives-ouvertes.fr/tel-00547777/

Chiron, C., Jambaque, I., Nabbout, R., Lounes, R., Syrota, A., & Dulac, O. (1997). The right brain hemisphere is dominant in human infants. *Brain, 120*, 1057–1065. http://dx.doi.org/10.1093/brain/120.6.1057

Cohen, D. J., Detlor, J., Young, J. G., & Shaywitz, B. A. (1980). Clonidine ameliorates Gilles de la Tourette syndrome. *Archives of General Psychiatry, 37*, 1350–1357. http://dx.doi.org/10.1001/archpsyc.1980.01780250036004

Cruz, A. A. V., Garcia, D. M., Pinto, C. T., & Cechetti, S. P. (2011). Spontaneous eyeblink activity. *The Ocular Surface, 9* 29–41. doi:10.1016/S1542-0124(11)70007-6

Deuschl, G., & Goddemeier, C. (1998). Spontaneous and reflex activity of facial muscles in dystonia, Parkinson's disease, and in normal subjects. *Journal of Neurology, Neurosurgery & Psychiatry, 64*, 320–324.

Doane, M. G. (1980). Interaction of eyelids and tears in corneal wetting and the dynamics of the normal human eyeblink. *American Journal of Ophthalmology, 89*, 507–516. http://dx.doi.org/10.1016/0002-9394(80)90058-6

Dreisbach, G., Müller, J., Goschke, T., Strobel, A., Schulze, K., Lesch, K.-P., & Brocke, B. (2005). Dopamine and cognitive control: The influence of spontaneous eyeblink rate and dopamine gene polymorphisms on perseveration and distractibility. *Behavioral Neuroscience, 119*, 483–490. http://dx.doi.org/10.1037/0735-7044.119.2.483

Esteban, Á., Traba, A., & Prieto, J. (2004). Eyelid movements in health and disease. The supranuclear impairment of the palpebral motility. *Neurophysiologie Clinique/Clinical Neurophysiology, 34*, 3–15. doi:10.1016/j.neucli.2004.01.002

Fowler, N. (2011). *Emotion matching and emotion regulation in infancy* (PhD thesis). Cardiff University. Retrieved from http://orca.cf.ac.uk/9452/

Freudenthaler, N., Neuf, H., Kadner, G., & Schlote, T. (2003). Characteristics of spontaneous eyeblink activity during video display terminal use in healthy volunteers. *Graefe's Archive for Clinical and Experimental Ophthalmology, 241*, 914–920. http://dx.doi.org/10.1007/s00417-003-0786-6

Glick, S. D., Ross, D. A., & Hough, L. B. (1982). Lateral asymmetry of neurotransmitters in human brain. *Brain Research, 234*, 53–63. doi:10.1016/0006-8993(82)90472-3

Goldberg, T. E., Maltz, A., Bow, J. N., Karson, C. N., & Leleszi, J. P. (1987). Blink rate abnormalities in autistic and mentally retarded children: Relationship to dopaminergic activity. *Journal of the American Academy of Child & Adolescent Psychiatry, 26*, 336–338.

Holland, M. K., & Tarlow, G. (1972). Blinking and mental load. *Psychological Reports, 31*, 119–127. http://dx.doi.org/10.2466/pr0.1972.31.1.119

Jutkiewicz, E. M., & Bergman, J. (2004). Effects of dopamine D1 ligands on eye blinking in monkeys: Efficacy, antagonism, and D1/D2 interactions. *Journal of Pharmacology and Experimental Therapeutics, 311*, 1008–1015. doi:10.1124/jpet.104.071092

Kaneko, K., & Sakamoto, K. (1999). Evaluation of three types of blinks with the use of electro-oculogram and electromyogram. *Perceptual and Motor Skills, 88*, 1037–1052. http://dx.doi.org/10.2466/pms.1999.88.3.1037

Karson, C. N. (1983). Spontaneous eye-blink rates and dopaminergic systems. *Brain, 106*, 643–653. http://dx.doi.org/10.1093/brain/106.3.643

Karson, C. N., Berman, K. F., Donnelly, E. F., Mendelson, W. B., Kleinman, J. E., & Wyatt, R. J. (1981). Speaking, thinking, and blinking. *Psychiatry Research, 5*, 243–246. http://dx.doi.org/10.1016/0165-1781(81)90070-6

Karson, C. N., Burns, R. S., LeWitt, P. A., Foster, N. L., & Newman, R. P. (1984). Blink rates and disorders of movement. *Neurology, 34*, 677–677. http://dx.doi.org/10.1212/WNL.34.5.677

Karson, C. N., Dykman, R. A., & Paige, S. R. (1990). Blink rates in schizophrenia. *Schizophrenia Bulletin, 16*, 345–354. http://dx.doi.org/10.1093/schbul/16.2.345

Kleven, M. S., & Koek, W. (1996). Differential effects of direct and indirect dopamine agonists on eye blink rate in cynomolgus monkeys. *Journal of Pharmacology and Experimental Therapeutics, 279*, 1211–1219.

Konrad, K., Gauggel, S., & Schurek, J. (2003). Catecholamine functioning in children with traumatic brain injuries and children with attention-deficit/hyperactivity disorder. *Cognitive Brain Research, 16*, 425–433. http://dx.doi.org/10.1016/S0926-6410(03)00057-0

Lawrenson, J. G., Birhah, R., & Murphy, P. J. (2005). Tear-film lipid layer morphology and corneal sensation in the development of blinking in neonates and infants. *Journal of Anatomy, 206*, 265–270. doi:10.1111/j.1469-7580.2005.00386.x

Leemann, B. (2004). *Impossibilité à la fermeture volontaire des paupières: une apraxie?* [Unable to close eyelids voluntarily: An apraxia?] (Doctoral dissertation). University of Geneva, Geneva.

Mackert, A., Woyth, C., Flechtner, K.-M., & Volz, H.-P. (1990). Increased blink rate in drug-naive acute schizophrenic patients. *Biological Psychiatry, 27*, 1197–1202. http://dx.doi.org/10.1016/0006-3223(90)90417-Z

Mantelli, F., Tiberi, E., Micera, A., Lambiase, A., Visintini, F., & Bonini, S. (2007). MUC5AC overexpression in tear film of neonates. *Graefe's Archive for Clinical and Experimental Ophthalmology, 245*, 1377–1381. http://dx.doi.org/10.1007/s00417-007-0602-9

McClelland, G. H. (2000). Nasty data: Unruly, III-mannered observations can ruin your analysis. In H. T. Reis & C. M. Judd (Eds.), *Handbook of research methods in social psychology* (pp. 393–411). Cambridge: Cambridge University Press.

Müller, J., Dreisbach, G., Brocke, B., Lesch, K.-P., Strobel, A., & Goschke, T. (2007). Dopamine and cognitive control: The influence of spontaneous eyeblink rate, DRD4 exon III polymorphism and gender on flexibility in set-shifting.

cogent ·· psychology

Brain Research, 1131, 155–162.
http://dx.doi.org/10.1016/j.brainres.2006.11.002

Pell, M. D., & Monetta, L. (2008). How Parkinson's disease affects non-verbal communication and language processing. *Language and Linguistics Compass, 2*, 739–759. http://dx.doi.org/10.1111/lnco.2008.2.issue-5

Petrikovsky, B. M., Kaplan, G., & Holsten, N. (2003). Eyelid movements in normal human fetuses. *Journal of Clinical Ultrasound, 31*, 299–301. http://dx.doi.org/10.1002/(ISSN)1097-0096

Ponder, E., & Kennedy, W. P. (1927). On the act of blinking. *Quarterly Journal of Experimental Physiology, 18*, 89–110.

Scheibel, A. B., Paul, L. A., Fried, I., Forsythe, A. B., Tomiyasu, U., Wechsler, A., … Slotnick, J. (1985). Dendritic organization of the anterior speech area. *Experimental Neurology, 87*, 109–117. http://dx.doi.org/10.1016/0014-4886(85)90137-2

Semmes, J. (1968). Hemispheric specialization: A possible clue to mechanism. *Neuropsychologia, 6*, 11–26. http://dx.doi.org/10.1016/0028-3932(68)90035-3

Slagter, H. A., Georgopoulou, K., & Frank, M. J. (2015). Spontaneous eye blink rate predicts learning from negative, but not positive, outcomes. *Neuropsychologia, 71*, 126–132. http://dx.doi.org/10.1016/j.neuropsychologia.2015.03.028

Slagter, H. A., Tomer, R., Christian, B. T., Fox, A. S., Colzato, L. S., King, C. R., … Davidson, R. J. (2012). PET evidence for a role for striatal dopamine in the attentional blink: Functional implications. *Journal of Cognitive Neuroscience, 24*, 1932–1940. http://dx.doi.org/10.1162/jocn_a_00255

Stern, J. A., Walrath, L. C., & Goldstein, R. (1984). The endogenous eyeblink. *Psychophysiology, 21*, 22–33. doi:10.1111/j.1469-8986.1984.tb02312.x

Taylor, J. R., Elsworth, J. D., Lawrence, M. S., Sladek, J. R., Roth, R. H., & Redmond, D. E. (1999). Spontaneous blink rates correlate with dopamine levels in the caudate nucleus of MPTP-treated monkeys. *Experimental Neurology, 158*, 214–220. http://dx.doi.org/10.1006/exnr.1999.7093

Toga, A. W., & Thompson, P. M. (2003). Mapping brain asymmetry. *Nature Reviews Neuroscience, 4*, 37–48. doi:10.1038/nrn1009

Toker, E., Yenice, Ö., Öğüt, M. S., Akman, İ., & Özek, E. (2002). Tear production during the neonatal period. *American Journal of Ophthalmology, 133*, 746–749. doi:10.1016/S0002-9394(02)01393-4

Tucker, D. M. (1981). Lateral brain function, emotion, and conceptualization. *Psychological Bulletin, 89*, 19–46. http://dx.doi.org/10.1037/0033-2909.89.1.19

Tucker, D. M., & Williamson, P. A. (1984). Asymmetric neural control systems in human self-regulation. *Psychological Review, 91*, 185–215. http://dx.doi.org/10.1037/0033-295X.91.2.185

Zaman, M. L., Doughty, M. J., & Button, N. F. (1998). The exposed ocular surface and its relationship to spontaneous eyeblink rate in elderly Caucasians. *Experimental Eye Research, 67*, 681–686. doi:10.1006/exer.1998.0571

Zametkin, A. J., Stevens, J. R., & Pittman, R. (1979). Ontogeny of spontaneous blinking and of habituation of the blink reflex. *Annals of Neurology, 5*, 453–457. doi:10.1002/ana.410050509

Cogent Psychology (ISSN: 2331-1908) is published by Cogent OA, part of Taylor & Francis Group.

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com