Universität Potsdam
Humanwissenschaftliche Fakultät

Reinhold Kliegl | Paula Teich | Urs Granacher | Thea Fühner

Developmental Gains in Physical Fitness Components of Keyage and Older-than-Keyage Third-Graders

Contribution to the Conference:
54. Jahrestagung der Arbeitsgemeinschaft für Sportpsychologie (asp 2022)
in Münster, 2022-06-16 (revised 2022-09-09)

Universität Potsdam

Published online on the
Publication Server of the University of Potsdam:
https://doi.org/10.25932/publishup-56087
https://nbn-resolving.org/urn:nbn:de:kobv:517-opus4-560870

Universität Potsdam
Humanwissenschaftliche Fakultät
Forschungsschwerpunkt Kognitionswissenschaften
Professur für Trainings- und Bewegungswissenschaft

Developmental Gains in Physical Fitness Components of Keyage and Older-than-Keyage Third-Graders

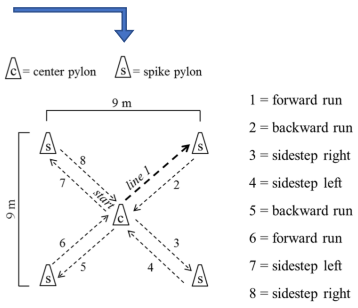
Reinhold Kliegl, Paula Teich, Urs Granacher, & Thea Fühner*

University of Potsdam, *German Federal Institute of Sport Science

54. Jahrestagung der Arbeitsgemeinschaft für Sportpsychologie (asp 2022)
Münster, 2022-06-16 (revised 2022-09-09).

EMOTIKON Test Battery and Age Groups

- Cardiorespiratory endurance (6-minute run)
- Coordination under time pressure (Star run)
- Speed (20-m sprint)
- PowerLOW (Standing long jump)
- PowerUP (Ball push test)
- Balance (One leg balance with closed eyes)



- Box-Cox transformation to pace score (m/s) for 20-m sprint and star run -> z-scores
- **Keyage children ("Stichlinge"):** Children enrolled according to legal keydate (30th Sept); third-grade age varies between 8 and 9 years (note: all analyses use age at test)
- **Older-than-keyage children (OTK; "Spätlinge"):** Children with delayed enrollment or repetition of class; third-grade age varies between 9 and 10 years

EMOTIKON: Keyage Children: Age x Sex x Task

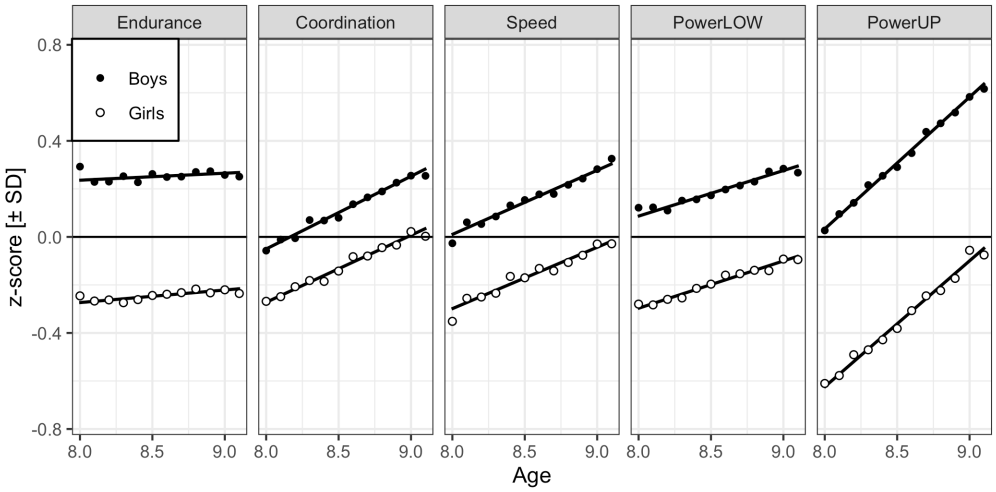


Figure from Fühner et al. (2021, *Scientific Reports*)
108,295 keyage children from third-grade primary schools
515 schools in Brandenburg
9 cohorts (2011 to 2019; cross-sectional data)

3

This is the signature result of EMOTIKON: The same linear growth during 3rd grade for boys and girls in each component, but large differences in growth rates. The take-off for this presentation is that the linear development is only obtained for keyage children.

EMOTIKON: All Children: Age x Sex x Task

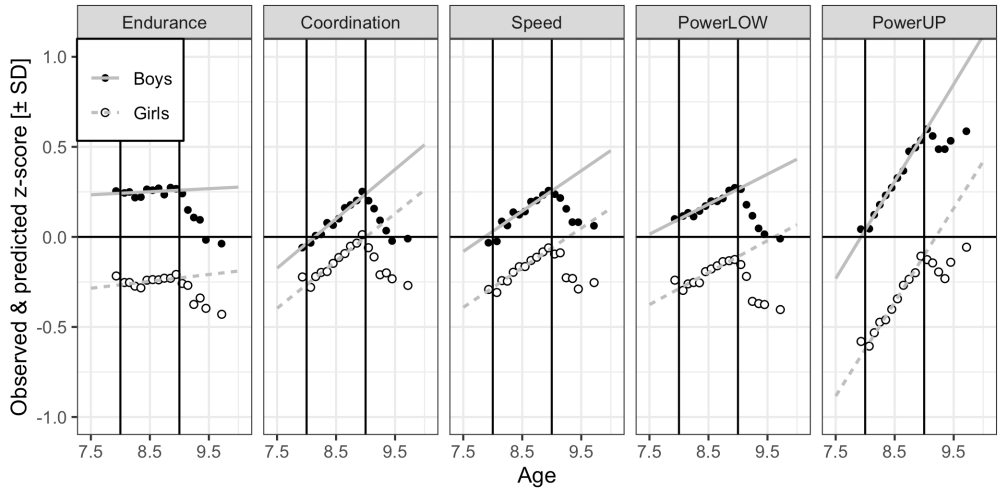


Figure from Fühner et al. (2022, *Scientific Reports*)
137,421 children (108,295 keyage; 2,586 YTK; 26,540 OTK)
515 schools in Brandenburg
9 cohorts (2011 to 2019; cross-sectional)

4

When we look at all children in third grade we add mostly older-than-keyage (OTK) children, specifically, 26,540 OTK children in the range from 9 up to 10 years. The grey lines show their expected performance if they were to develop at the rate of keyage children. Clearly they don't, but exhibit a remarkable decline in performance. Indeed, averaging across all children pretty much eliminates the age effect we saw on the previous slide. What accounts for this striking discontinuity of physical fitness?

Biological vs. Chronological Age

Spieler A (spät entwickelt)	
Alter:	14,2 Jahre
Körperhöhe:	153 cm
Körpermasse:	38,5 kg
PHV:	15,9 Jahre
YPHV:	-1,7 Jahre
Aufschlag:	135 km/h
CMJ:	33,4 cm
20 m Linearsprint:	3,34 s
Crunches:	50

Spieler B (früh entwickelt)	
Alter:	13,8 Jahre
Körperhöhe:	182 cm
Körpermasse:	80,3 kg
PHV:	12,0 Jahre
YPHV:	+1,8 Jahre
Aufschlag:	180 km/h
CMJ:	36,6 cm
20 m Linearsprint:	3,27 s
Crunches:	23

Source: Fühner, T., Kriemler, S., Woll, A., & Granacher, U. (2021). Körperliche Leistungsfähigkeit im Kontext von Wachstum und Reifung. In *Pädiatrische Sportmedizin* (pp. 23-33). Springer, Berlin, Heidelberg.

5

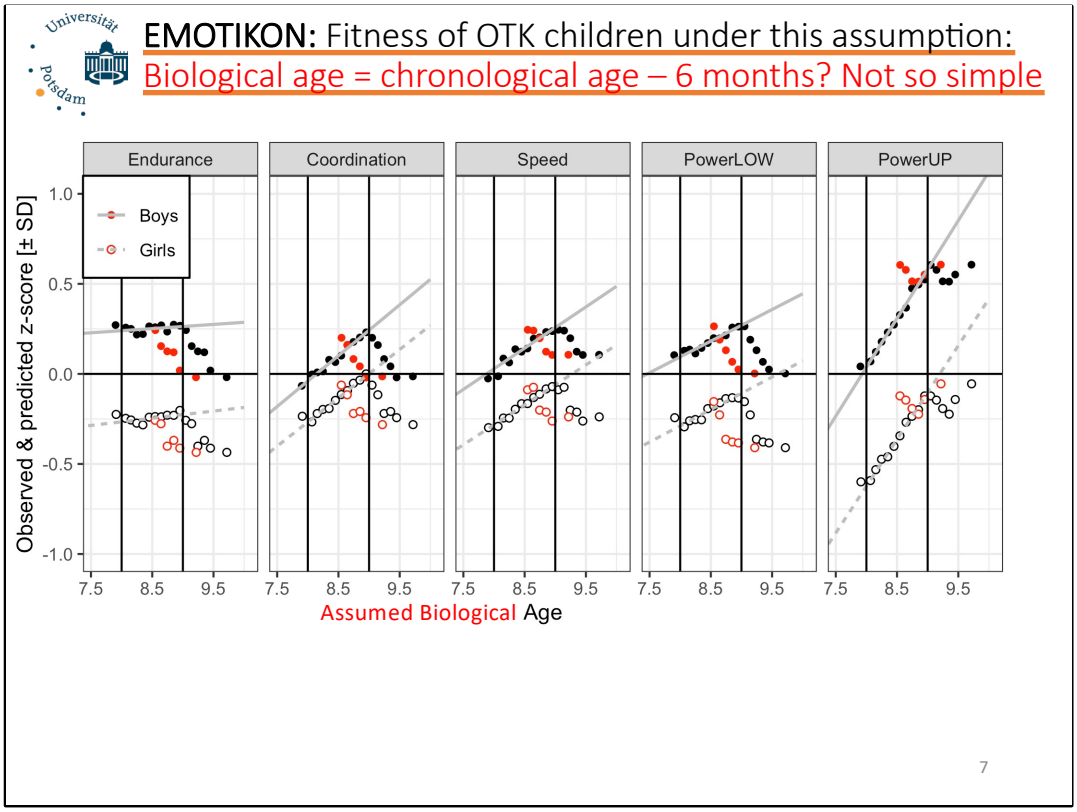
One problem with our analysis is that we know the children's chronological, but not their biological age. And, as you all know and shown in the picture, children of the same age can differ very much in their physical appearance which probably reflects their biological age.

Why are older-than-keyage (OTK) children physically less fit than keyage children? Four hypotheses

1. **OTK children are biologically younger than keyage children?**
   - Tested with cross-sectional data (Fühner et al., 2021, 2022)
   - Expected: With proxy of biological age OTK look like keyage children
2. **Some age-related physiological, motivational, or social change?**
   - Tested with longitudinal follow-up of keyage children
   - Expected: Decrease in physical fitness in fourth grade
3. **Age-related (temporary) developmental delay?**
   - Tested with longitudinal follow-up of both groups
   - Expected: OTK children catch up with keyage children in fourth grade
4. **Sustained difference in physical fitness?**
   - Tested with longitudinal follow-up of both groups
   - Expected: Difference between keyage and OTK children sustained (or larger)

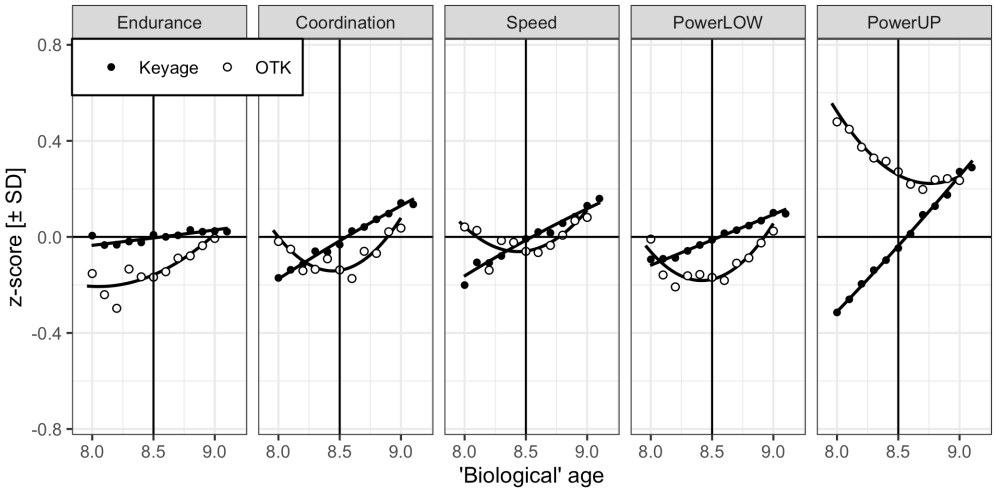
6

Given these results and what we know about biological vs. chronological age, we formulate four hypotheses about why OTK children might be physically less fit than keyage children. Probably most OTK children were held back a year, because the physician judged them to be not mature enough. Not being mature enough is another way of saying these children were biologically younger than their chronological age suggests. Therefore, we tested two proxies of biological age. If one of these proxies accounts for the differences, than we should also see development for OTK children in these cross-sectional data. There is also the possibility that something happens in the tenth year of life – some physiological change or some motivational or peer-related effects. We cannot rule out this explanation with cross-sectional data, but a longitudinal follow-up of keyage children will allow us to see whether they also experience a decline in performance when they are of the same chronological age as the older-than-keyage children in third grade. The third hypothesis is that OTK children's lower physical fitness (possibly due to being biologically younger) will be compensated with a developmental accelaration. We should see this longitudinally in a greater development from third to fourth grade for OTK than keyage children. The fourth hypothesis is a corollary of the third one: The differences we see in the third grade are simply maintained in fourth grade.



A simple possibility is that OTK children are biologically younger than keyage children by an average number of months. For example, when we move OTK children's means six months to the left, there is a kind of an alignment for PowerUP, but obviously this shift does not account for OTK's children's lower physical fitness in the other components. In these tasks, OTK children reveal a striking pattern: There is a distinct negative linear relation with age: The older the OTK children, the lower their physical fitness. And this leads to the second hypothesis about the role of biological age. Remember OTK children were held back because the physician judged them to be not mature enough for school. Now if the physician has some internal standard for this, then the biologically youngest OTK children are likely to be the chronologically oldest ones. In other words, the negative slope we see in this figure could be a selection-by-maturity effect.

EMOTIKON: Fitness of OTK children also under assumption: Biological age = 9 years - [(keydate – birthdate)/365] years



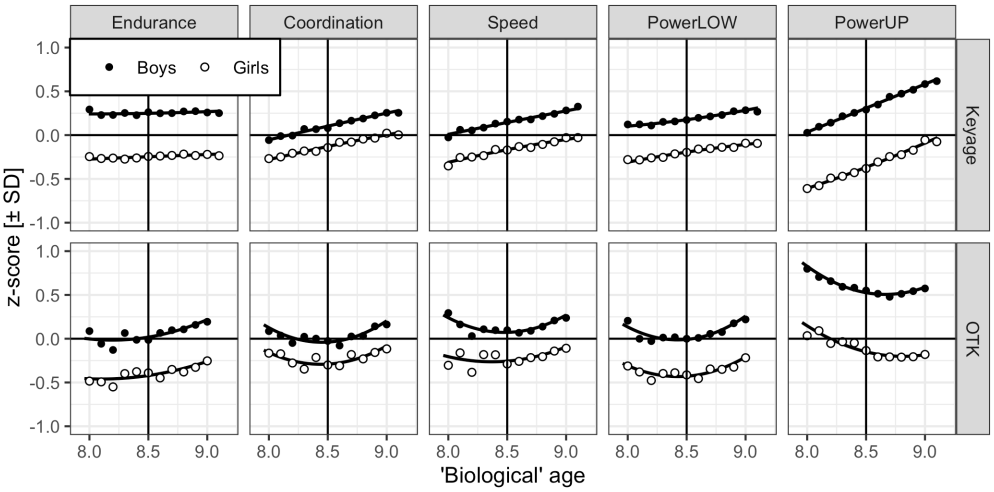
Assumption: **OTK children are delayed according to perceived maturity = biological age.** Then: Biologically older / chronologically younger OTK children exhibit growth in third grade; not all rates are in agreement with those of keyage children. Biologically younger / chronologically older OTK children are probably different.

8

There is a comparatively simple formula that transforms chronological age from 9 to 10 years into the mirrored biological age between 9 and 8 years. The open symbols shows the OTK children's data fitted to this proxy of biological age. The most important result is that the biologically **older** OTK children (i.e., 8.5 to 9.0 years) the development is linear positive for all tasks. Moreover, the slope for the first four components are similar to each other and steeper than the one for PowerUP. Note that the biologically older OTK children are the chronologically younger OTK children (i.e., they are between 9.0 and 9.5 years old). Results are not very clear for the biologically younger (chronologically older) OTK children for the first four components. Again, their performance on PowerUP is strikingly different.

How do the results align with those from the keyage children shown with the filled symbols? For them we assume that biological age is normally distributed around each chronological age. There is no selection bias; everything averages out. The comparison of keyage and OTK children reveals that we are probably on the right track, but that the alignment is also not perfect for the biologically older OTK children, especially for endurance. More work is needed here, but for a zero-parameter transformation the results are very encouraging. The most striking difference, that is a qualitative difference, is observed for PowerUP. This is the only component were OTK outperform keyage children for almost the entire range of biological age.

EMOTIKON: Fitness of OTK children also under assumption: Biological age = 9 years - [(keydate – birthdate)/365] years



Assumption: **OTK children are delayed according to perceived maturity = biological age.** Then: Biologically older / chronologically younger OTK children exhibit growth in third grade; not all rates are in agreement with those of keyage children. Biologically younger / chronologically older OTK children are probably different.

9

The pattern described in the last slide is very similar for boys and girls. This provides strong evidence for the reliability of the effects.

EMOTIKON Longitudinal Study in Potsdam-Mittelmark

Cohort 2020/21

- Third grade with 37 schools

Cohort 2021/22

- Third grade with 38 schools (88,4 % of public schools)
- Fourth grade with 36 schools

Cohort 2022/23

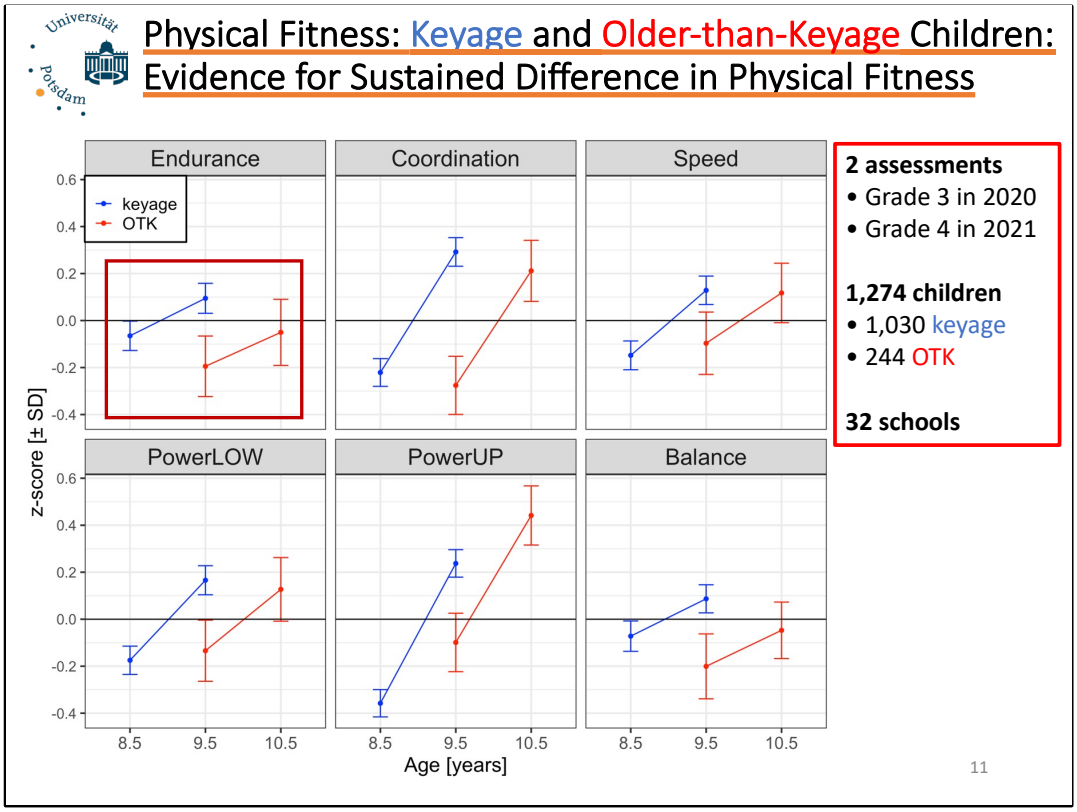
- Planned for grades 3, 4, und 5

Analysis with Linear Mixed Model with …

- **Child** and **School** as random factors with …
- … task-related variance components and correlation parameters

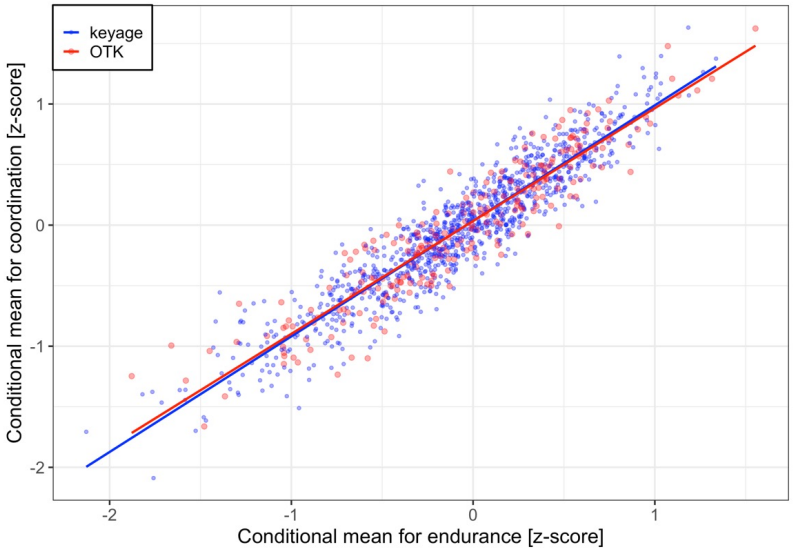
10

Now to the longitudinal data. For one of the Brandenburg counties - Potsdam-Mittelmark - we were able to retest the 2020 cohort in 2021. In 2022, we hope to restest them for a third time and retest the 2021 cohort a second time.



We are switching back to chronological age. The results are straightforward. First, both keyage (blue lines) and OTK (red lines) children improve their physical fitness in the six components from third grade to fourth grade. Second, they improve by about the same amounts; none of the interactions in the six panels is significant; the lines in each panel are statistically parallel. Third, we can compare keyage and OTK children at the same chronological age of 9.5 years. And here the difference is significant in each panel in favor of keyage children. These results rule out the second and third hypotheses for all fitness components; there is no evidence for an unexpected physiological, motivational, or social change for keyage children or compensatory catchup for OTK children. The results are in agreement with the fourth hypothesis: There is a sustained difference in physical fitness between the two groups. These results still need to be re-evaluated with respect to biological age, ideally based on anthropometric data.

Physical Fitness: Keyage and OTK Children: No Evidence for Subgroups in Conditional Means



2 assessments
- Grade 3 in 2020
- Grade 4 in 2021

1,274 children
- 1,030 keyage
- 244 OTK

32 schools

12

Children-related conditional means of the tests might reveal a clustering of OTK children indicative of different subtypes. The slide shows the correlation between the conditional means for cardiorespiratory endurance and the conditional means for coordination for keyage and OTK children. There is no support for our exploratory speculation. Indeed, OTK children appear to perfectly mixed with keyage children, suggesting that fixed and random effects of the LMM adequately absorbed variance related to differences between keyage and OTK children.

Summary

1. **Some OTK children may be biologically younger than keyage children**
   - Important source of variance, not only for sports, also other subjects
   - Does not explain **all** of the cross-sectional / longitudinal profiles
   - Anthropometric data – mass and height (standing, sitting) – needed
2. **Age-related physiological, motivational, or social changes are unlikely sources of the difference**
3. **There is no evidence for an age-related (temporary) developmental delay from third to fourth grade**
4. **No evidence for retest effect on any of the components (data from 37 *new* keyage fourth grade children; not shown in detail)**
5. **Results are compatible with sustained delay from third to fourth grade**
   - Validates delay in enrollment / repetition of grade
   - Might be taken into account for grading (focus on intra-individual development rather than on inter-individual differences)
   - Question: Are there different subgroups of OTK children?

13

Thank you!

Contact us:

Reinhold Kliegl: reinhold.kliegl@uni-potsdam.de

Paula Teich: paula.teich@uni-potsdam.de

EMOTIKON website: www.uni-potsdam.de/emotikon

EMOTIKON-Podcast

www.uni-potsdam.de/de/emotikon/podcast

You can follow EMOTIKON updates by joining our newsletter and listening to the EMOTIKON podcast (www.uni-potsdam.de/de/emotikon/podcast).