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Circadian rhythms in handwriting kinematics and legibility

Isabelle Jasper [a], Marijke Gordijn [b], Andreas Häußler [a], Joachim Hermsdörfer [a,*]

[a] Clinical Neuropsychology Research Group (EKN), Clinic for Neuropsychology, München-Bogenhausen Hospital, Dachauer Strasse 164, D-80992 Munich, Germany
[b] Department of Chronobiology, University of Groningen, Kerklaan 30, 9751 NN Haren, The Netherlands

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ABSTRACT

The aim of the present study was to analyze the circadian rhythmicity in handwriting kinematics and legibility and to compare the performance between Dutch and German writers. Two subject groups underwent a 40 h sleep deprivation protocol under Constant Routine conditions either in Groningen (10 Dutch subjects) or in Berlin (9 German subjects). Both groups wrote every 3 h a test sentence of similar structure in their native language. Kinematic handwriting performance was assessed with a digitizing tablet and evaluated by writing speed, writing fluency, and script size. Writing speed (frequency of strokes and average velocity) revealed a clear circadian rhythm, with a parallel decline during night and a minimum around 3:00 h in the morning for both groups. Script size and movement fluency did not vary with time of day in neither group. Legibility of handwriting was evaluated by intra-individually ranking handwriting specimens of the 13 sessions by 10 German and 10 Dutch raters. Whereas legibility ratings of the German handwriting specimens deteriorated during night in parallel with slower writing speed, legibility of the Dutch handwriting deteriorated not until the next morning. In conclusion, the circadian rhythm of handwriting kinematics seems to be independent of script language at least among the two tested western countries. Moreover, handwriting legibility is also subject to a circadian rhythm which, however, seems to be influenced by variations in the assessment protocol.

* Corresponding author. Tel.: +49 89 1577895; fax: +49 89 156781.
E-mail address: Joachim.Hermsdoerfer@extern.lrz-muenchen.de (J. Hermsdörfer).

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1. Introduction

Humans are, like most organisms, subject to the rhythmical change of night and day that is related to the 24 h cycle of the earth's rotation. As an adaptation to this 24 h cycle an endogenous biological clock has evolved. The term circadian (about 1 day; Halberg, 1959) was introduced because the biological clock adopts its own period that can deviate from 24 h when isolated from al environmental time cues (Zeitgeber). The circadian clock controls all levels of biological processes, from gene expression to behavior.

In motor performance a well documented circadian rhythm is maximum strength with a maximum in muscle strength in the early evening (between 17:00 and 19:00 h; Atkinson, Coldwells, Reilly, & Waterhouse, 1993) and least strength between 5:00 h (Stolz, Aschoff, Born, & Aschoff, 1988) and 6:30 h (Ilmarinen, Ilmarinen, Korhonen, & Nurminen, 1980) in the early morning. Fine motor skills have been analyzed less frequently. In a few studies influences of the circadian clock have been shown, e.g., for manual dexterity (Monk et al., 1997), and tracking performance (van Eekelen & Kerkhof, 2003) with minima between 5:00 h (manual dexterity) and 8:00 h (tracking accuracy) in the morning.

Handwriting is described as one of the most demanding and complex fine motor functions of humans (Blank, Miller, & von Voss, 2000), involving motor control of the fingers, wrist, and arm, plus distinct grip force adjustments. Analyzing handwriting performance as an example for fine motor skills is obvious, because handwriting is a highly automated, over-learned sensorimotor skill that is frequently performed in everyday life (van Galen, 1990) and the motor process of handwriting can be precisely and objectively analyzed using kinematic analyses. Furthermore, the quality of handwriting can be evaluated in terms of the legibility of the written output.

The relevance of legibility of handwritings and of precise fine motor functions is obvious in medical professionals; for example, the risk of medication errors is increased if nurses, pharmacists, and other health care professionals cannot read the physicians' handwritten medication orders (Brodell, Helms, KrishnaRao, & Bredle, 1997; Cheeseman & Boon, 2001; Winslow, Nestor, Davidoff, Thompson, & Borum, 1997) and laparoscopic surgical skills were shown to be impaired due to call-associated sleep deprivation (Eastridge et al., 2003; Taffinder, McManus, Gul, Russell, & Darzi, 1998). Furthermore, health care is a typical example of an industry requiring work at times beyond the normal waking day.

The effect of circadian rhythmicity on motor aspects and legibility of handwriting performance has, however, only rarely been examined. Glenville, Broughton, Wing, and Wilkinson (1978) for example showed a significant increase of writing size in the afternoon compared to the morning. Analyzing the effect of sleep deprivation on handwriting, Glenville et al. (1978) reported a tendency to write smaller, whereas Tucha, Mecklinger, Walitza, and Lange (2006) showed no influence on the quality of the handwriting specimens, assessed by ratings of legibility and accuracy. By contrast, kinematic analyses of handwriting revealed significantly faster and more fluent movements after one night of sleep loss (Tucha et al., 2006). Recently, we were able to demonstrate a circadian rhythm in the kinematics of handwriting in two studies (Jasper, Häußler, Baur, Marquardt, & Hermsdörfer, 2009; Jasper, Häußler, Marquardt, & Hermsdörfer, 2009). Especially the frequency of handwriting, as a measure of movement speed, was proven to show circadian rhythmicity with a decrease in writing speed during the evening and night, an early morning minimum at 3:16 h (Jasper, Häußler, & Baur, et al., 2009) and 3:30 h (Jasper, Häußler, & Marquardt, et al., 2009) followed by a recovery in writing speed the next morning.

Since the two studies by Jasper, Häußler, and Baur, et al. (2009) and Jasper, Häußler, and Marquardt, et al. (2009) were performed under similar constant environmental conditions (Constant Routine protocol) with similar subjects, a statistical comparison of these published data would confirm the endogenous character of the circadian rhythm in the kinematics of handwriting. Although the two studies were performed with German and Dutch writers, we expected that circadian rhythms of the writing kinematics were not significantly different for both languages. A Constant Routine (CR) protocol is characterized by keeping the environmental (e.g., light) and behavioral (e.g., meals, movement) conditions constant while subjects are awake for at least 24 h (Czeisler et al., 1989; Duffy & Dijk, 2002) and therefore particularly suitable for recording circadian rhythms.

A further aim of the present study, however, was to determine whether legibility is sensitive to circadian rhythmicity. Therefore, we post hoc evaluated legibility in the handwriting data that had