Effects of Biscriptuality on Graphomotor Coordination Dynamics

Gaëlle ALHADDAD [a], Jérémy DANNA [a], Céleste YOUNES-HARB [b], Jean-Luc VELAY [a] and Marieke LONGCAMP [a]
[a] *Laboratoire de Neurosciences Cognitives, UMR 7291, CNRS and Aix-Marseille Université Marseille, FRANCE*
[b] *Institut de Psychomotricité, Université Saint-Joseph de Beyrouth Beirut, LEBANON*
gaelle.alhaddad@univ-amu.fr, jeremy.danna@univ-amu.fr, celeste.younes@usj.edu.lb, jean-luc.velay@univ-amu.fr, marieke.longcamp@univ-amu.fr.

Abstract. Biscriptuality is the ability to write in two different writing systems. The aim of this study was to examine the effects of biscriptuality on graphomotor coordination dynamics in right-handed adults. Thirty-four French monoscriptuals and 34 French-Arabic biscriptual participants traced series of loops in two writing directions, and in two senses of rotation. We found that biscriptuals displayed a general advantage over monoscriptuals in terms of spontaneous tracing frequency, while both groups displayed a preference for the left-to-right direction. This finding provides novel evidence on the effect of script writing expertise on graphomotor patterns by showing that biscriptuality could be an asset.
Keywords: Biscriptuality; Graphomotor Coordination; Writing; Spontaneous Frequency.

1. Introduction

Handwriting is a rhythmic movement that can be described as a linear combination of oscillatory movements in the orthogonal plane generated by wrist and finger movements (Hollerbach, 1981). A promising way to study graphomotor control is the dynamic approach to coordination. This approach considers that motor coordination self-organizes itself into a spatio-temporal structure called a pattern generated by coupled oscillators (Kelso, 1995). The dynamical systems approach has successfully explained the stability of graphomotor patterns (Athènes et al., 2004; Sallagoïty et al., 2004).

Yet, individual differences and task conditions influence how graphomotor patterns are learned, practiced and (de)stabilized. An important source of variation in the acquisition and mastery of graphomotor patterns lies in the characteristics and number of the practiced scripts. Recently, there has been a growing interest in the practice of two or more scripts, otherwise known as biscriptuality, the ability to write in two different writing systems (Usanova, 2019). Latin-Arabic biscriptuality remains one of the less studied pairs of scripts. From a graphomotor point of view, Arabic and Latin scripts are opposite in terms of writing direction and sense of rotation: Latin is written from left-to-right, with most letters arranged counterclockwise, while Arabic is written from right-to-left, with most letters traced clockwise (van Sommers, 1984).

Simultaneously mastering two writing systems with very opposite characteristics could either be advantageous or detrimental for writers. While this issue has most often been debated in bilingualism research on speech, it has not yet been addressed in the writing domain.

The aim of this paper is to investigate whether biscriptuality has an influence on the stability of graphomotor patterns. To this end, right-handed French monoscriptual and Arabic-French biscriptual participants traced loops in two writing directions (left-to-right and right-to-left) and senses of rotation (clockwise and counterclockwise). Data were used to identify differences in the spontaneous tracing frequency, the relative phase (RP) of the loops, their stability, the slant of the loops and their variability.

2. Method

2.1 **Participants:**

Thirty-four right-handed biscriptual participants (mean age 26.30, 20 females) and 34 right-handed age-matched monoscriptual participants (mean age 26.04, 22 females) volunteered for the experiment. To take part in this study, all participants had to meet the following requirements: (1) to be aged between 20 and 40 years old, (2) to speak fluently and write in equal proficiency French and/or Arabic, meaning that all biscriptual participants must be native Arabic speakers and writers. Biscriptuals had to be equally exposed to both scripts, in an equal manner within their entire educational enrolment (3) to demonstrate an established right-handedness.
A comprehensive questionnaire on handwriting habits was administered to evaluate the quality and quantity of writing practices in both scripts.

2.2 **Task and Procedure:**

The participants were asked to copy upscaled and downscaled loops starting from left-to-right then right-to-left, from an indicated position on a paper fixed on a Wacom® 4 Medium tablet. The order of the conditions was switched randomly between participants. The loops were copied in 10x1 cm rectangles from a starting point and

until the end of the rectangle. The number of loops to produce was not indicated in the instructions, but the participants were required to copy the model without pen lifts, within the rectangle without necessarily touching its borders, at spontaneous speed.

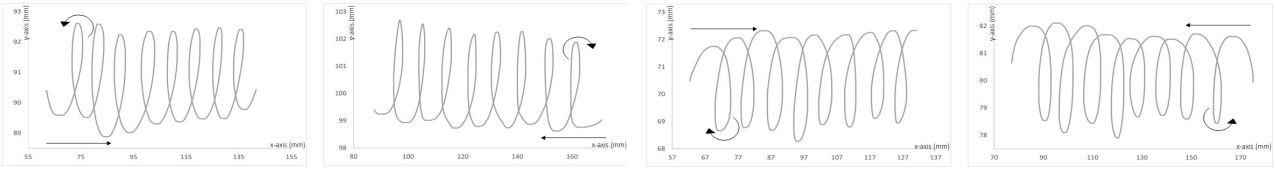

Figure 1. A participant's sample of the four graphomotor conditions: left-to-right and right-to-left writing directions / counterclockwise and clockwise senses of rotation.

2.3 **Variables:**

In the graphomotor coordination dynamics approach, the relative phase (RP), the slant, and spontaneous tracing frequency of the loops are typically used as measures of trace stability and its degree of coordination (Athènes et al., 2004). Five variables were analysed:

1) The frequency corresponds to the number of loops drawn per second. This variable is an indicator of speed.
2) The mean RP corresponds to the preferred graphomotor coordination pattern or attractor. Values are located between 0° (line) and 90° (circle), preferred RPs are typically located at around 45° (Athènes et al., 2004).
3) The SD of the RP was also extracted to indicate the stability of the scripter's coordination. Lower values indicate that the RP is stable across the 8 loops while higher values show variability.
4) The mean slant indicated the inclination angle of the axis of the loop relative on the baseline, with minimal and maximal values of 0° and 180°, indicating the loop's slant orientation. Values between 0° and 90° indicated a rightward slant, whereas 90° to 180° values meant that the loops were slanted to the left.
5) The SD of the slant is an indicator of the slant variability across loops. Values close to 1 show stability in the loops' slant, while those leaning towards 0 demonstrate variability.

2.4 **Statistical Analysis**:

The data analysis was performed on the first eight correct ellipses within each series of loops. Based on cycle-by-cycle analysis, we calculated the closest theoretical ellipse for each drawn loop. This transformation extracted the RP (mean and SD) corresponding to the eccentricity of the ellipse, and its slant (mean and SD). The spontaneous frequency was also calculated. Data analysis was performed on the four conditions, following the 2 writing directions (left-to-right and right-to-left) x 2 senses of rotation (counterclockwise and clockwise) factorial design.

The data were analysed using linear mixed models via RStudio with the lmerTest package. The effects of group, writing direction, sense of rotation, and interactions between group and the two other variables on frequency, RP and slant were tested. The model also included the age and gender as control variables.

3. Results

All mixed-model effects are reported in Table 1 and significant effects represented in Figure 2.

Table 1. Mixed effects models on the frequency, RP and slant of loops in biscriptual and monoscriptual participants.

FREQUENCY				
	B	*SE*	*t*	*p*
(Intercept)	2.43	0.59	4.07	0.000***
Group	-0.46	0.18	-2.53	0.013*
Sense of rotation	-0.15	0.05	-2.97	0.003**
Writing direction	0.35	0.05	6.96	0.000***
Group*Sense of rotation	0.06	0.07	0.89	0.373
Group*Writing direction	-0.17	0.07	-2.47	0.014*
Age	-0.00	0.02	-0.20	0.837
Gender	-0.01	0.18	-0.08	0.934

RELATIVE PHASE								
	Mean RP				RP SD			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*

(Intercept)	62.75	7.44	8.42	0.000***	8.40	1.60	5.24	0.000***
Group	-1.18	2.66	-0.44	0.658	1.60	0.66	-0.12	0.898
Sense of rotation	-3.26	1.57	-2.07	0.039*	-0.08	0.48	-0.78	0.435
Writing direction	-8.12	1.57	-5.16	0.000***	0.66	0.48	-2.38	0.017*
Group*Sense of rotation	0.09	2.22	0.043	0.965	-1.15	0.68	-0.07	0.941
Group*Writing direction	3.29	2.22	1.478	0.141	0.48	0.68	-0.14	0.889
Age	-0.15	0.27	-0.57	0.566	-0.37	0.05	0.13	0.896
Gender	-1.74	2.21	-0.78	0.434	0.48	0.46	0.09	0.921

SLANT

	Mean slant				Slant SD			
	B	*SE*	*t*	*p*	*B*	*SE*	*t*	*p*
(Intercept)	78.80	9.12	8.63	0.000***	-1.16	0.51	-2.25	0.027*
Group	-2.27	3.59	-0.63	0.527	0.19	0.20	0.93	0.351
Sense of rotation	-3.25	2.46	-1.32	0.187	0.21	0.14	1.54	0.124
Writing direction	-2.68	2.46	-1.08	0.277	0.67	0.14	4.79	0.000***
Group*Sense of rotation	7.69	3.48	2.20	0.028*	-0.07	0.19	-0.39	0.690
Group*Writing direction	0.19	3.48	0.05	0.955	-0.26	0.19	-1.32	0.185
Age	0.34	0.33	1.02	0.308	0.02	0.01	1.38	0.171
Gender	-7.40	2.69	-2.78	0.007**	0.03	0.15	0.24	0.808

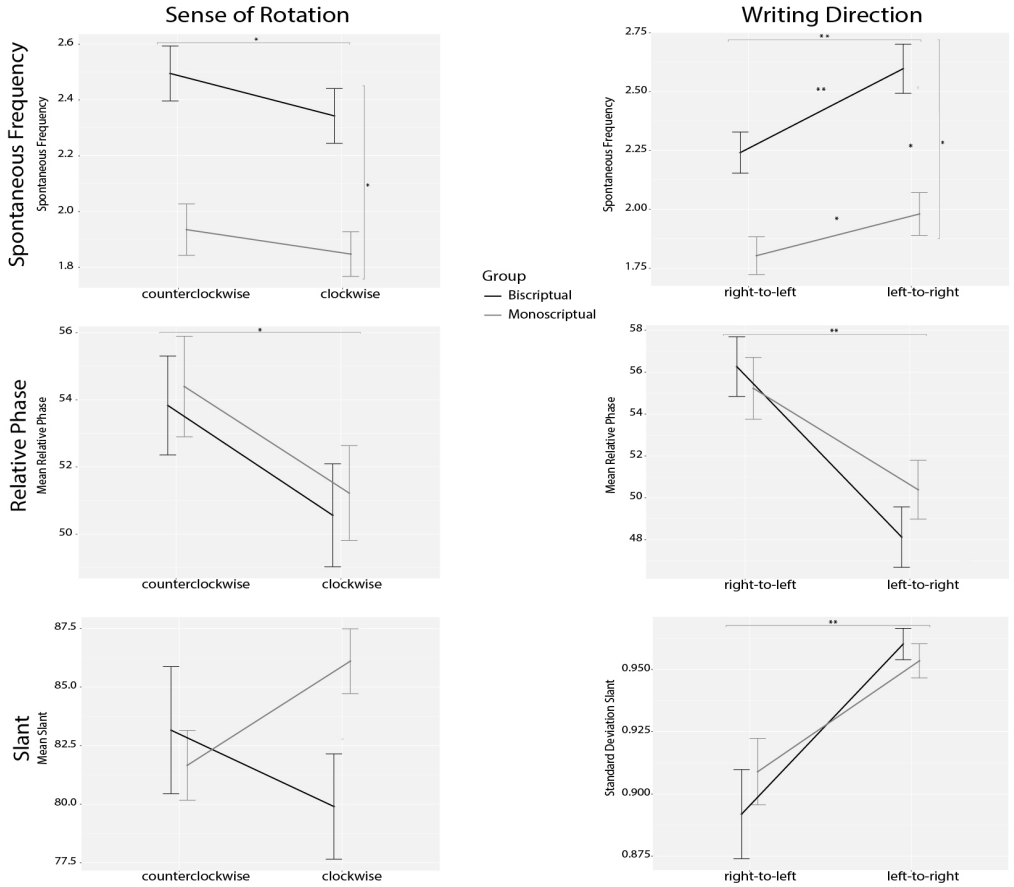

Figure 2. Effects of sense of rotation and writing direction on the frequency, RP and slant of loops in biscriptual and monoscriptual participants. Error bras represent 95% confidence intervals. The lines with asterisks represent the main effects and the asterisks alone represent the contrasts tested when the interaction was significant. *: p < .05, **: p < .001.

4. Discussion and Conclusion

Biscriptuality, an asset for graphomotor control

Our results suggest that expertise in two writing systems with very different graphomotor constraints could lead to modifications in the spontaneous pace of hand movements during loop tracing. Higher frequencies show that

biscriptuals display an advantage in spontaneous tracing compared to monoscriptuals. In handwriting research, less demanding conditions typically yield the highest frequencies, while more demanding handwriting tasks are performed at lower frequencies (Saarinen, 2020).

Changes in rhythmic behavior with expertise have been explained by improved motor control abilities. The more efficient motor control in biscriptuals than monoscriptuals could be consequent to the intensive simultaneous training in two different scripts of the biscriptual group monoscriptuals (Matta Abizeid et al., 2017).

Moreover, prolonged exposure to a graphic system has a direct impact on directional preferences (Goodnow et al., 1973). It is therefore possible that the greater directional preferences of biscriptual participants in terms of tracing frequency are due to adaptations to a more frequent use of Latin script in this group.

The impact of writing direction and sense of rotation on the stability of graphomotor patterns

The massive effect of writing direction indicates that the directional progression of the movements strongly impacts the stability indexes of graphomotor patterns, independently of expertise. When the patterns were produced with an added arm translation, we found RP values of approximately 50-55°. This differs from the typical value of preferential coordination patterns of 45° RP when ellipses are produced without arm translation (Athènes et al., 2004; Sallagoïty et al., 2004). This indicates that directional progression is an important factor to account for when studying graphomotor coordination, even though it has been relatively overlooked in handwriting research.

Furthermore, all participants displayed more stable graphomotor patterns when the loops were traced with a left-to-right progression. This could be due to the right-handedness of the participants as handedness is known to influence orientation preferences (van Sommers, 1984). Movements directed away from the body are performed faster than movements directed towards the body, so outward movements from left-to-right are easier for right-handers.

Moreover, biscriptual participants also reported writing more often in Latin than Arabic. It is therefore possible that the directional preferences of biscriptual participants are due to either biomechanical constraints on the right hand, adaptations to a more frequent use of Latin script, or a combination of both.

Finally, counterclockwise rotations were traced with higher frequencies than clockwise rotations for all participants. This effect is more difficult to interpret as it is coupled with an increase in RP, indicating higher constraints. This result could be explained by conflicts between biomechanical preferences for clockwise rotations and writing habits where counterclockwise rotations are dominant (Meulenbroek et al., 1993).

In conclusion, these differences in graphomotor coordination dynamics between monoscriptuals and biscriptuals open new perspectives in handwriting research. Knowing how script writing expertise positively affects motor behavior opens a wide range of possible applications. In the domains of remediation and education, these results could possibly influence the learning choices and strategies of different scripts in academic contexts. Since biscriptuality and its specific effects on graphomotor coordination dynamics are still largely unexplored, interesting perspectives arise from comparisons with other biscriptual participants who are experts in alphabets both written from left-to-right such as Latin and Cyrillic, or right-to-left such as Arabic and Hebrew.

.

References

Athènes, S., Sallagoïty, I., Zanone, P.-G., & Albaret, J.-M. (2004). Evaluating the coordination dynamics of handwriting. Human Movement Science, 23(5), 621-641.Simon, J.C. (1992). Off-line Cursive Word Recognition, *Proc. of the IEEE, 80(7),* 1150-1161.

Goodnow, J., Friedman, S. L., Bernbaum, M., & Lehman, E. B. (1973). Direction and Sequence in Copying : The Effect of Learning to Write in English and Hebrew. Journal of Cross-Cultural Psychology, 4(3), 263-282.

Hollerbach, J. M. (1981). An oscillation theory of handwriting. Biological Cybernetics, 39(2), 139-156.

Kelso, J. A. S. (1995). Dynamic patterns : The self-organization of brain and behavior. (p. xvii, 334). The MIT Press.

Matta Abizeid, C., Tabsh Nakib, A., Younès Harb, C., Ghantous Faddoul, S., & Albaret, J.-M. (2017). Handwriting in Lebanese bigraphic children : Standardization of the BHK Scale. Journal of Occupational Therapy, Schools, & Early Intervention, 10(4), 420-435.

Meulenbroek, R. G. J., Vinter, A., & Mounoud, P. (1993). Development of the start-rotation principle in circle production. British Journal of Developmental Psychology, 11(3), 307-320.

Saarinen, T., Kujala, J., Laaksonen, H., Jalava, A., & Salmelin, R. (2020). Task-Modulated Corticocortical Synchrony in the Cognitive-Motor Network Supporting Handwriting. Cerebral Cortex, 30(3), 1871-1886.

Sallagoïty, I., Athènes, S., Zanone, P.-G., & Albaret, J.-M. (2004). Stability of Coordination Patterns in Handwriting : Effects of Speed and Hand. Motor Control, 8(4), 405-421.

Usanova, I. (2019). Biscriptuality : Writing skills among German-Russian adolescents (Vol. 8). John Benjamins Publishing Company.

van Sommers, P. (1984). Drawing and Cognition : Descriptive and Experimental Studies of Graphic Production Processes (1re éd.). Cambridge University Press.